

**EPA Superfund
Record of Decision Amendment:**

CORNHUSKER ARMY AMMUNITION PLANT

EPA ID: NE2213820234

OU 01

HALL COUNTY, NE

09/26/2001



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

**REGION VII
901 NORTH 5TH STREET
KANSAS CITY, KANSAS 66101**

October 2, 2001

U.S. Environmental Protection Agency
Superfund Docket (5202G) Attn: Marty Graves
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Dear Mr. Graves:

Enclosed is a copy of the September 26, 2001, Record of Decision for the Cornhusker Army Ammunition Plant (Operable Unit No. 01), Grand Island, Nebraska. If you have any questions, please contact me at 913/551-7415.

Sincerely,

A handwritten signature in black ink, reading "Lynette Motley", is positioned above the printed name.

Lynette Motley
Superfund Division

Enclosure

OU1 ROD AMENDMENT

CORNHUSKER ARMY AMMUNITION PLANT GRAND ISLAND, NEBRASKA



Prepared for
U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

April 2001

URS

101 South 108th Avenue
Omaha, Nebraska 68154
Project No. 45F0000009.00

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SUPERFUND DIVISION

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SITE NAME AND LOCATION

Cornhusker Army Ammunition Plant (CHAAP), Grand Island, Nebraska.

STATEMENT AND BASIS OF PURPOSE

This Record of Decision (ROD) Amendment presents the new proposed remedy for Operable Unit One (OU1) groundwater at CHAAP, Grand Island, Nebraska. The ROD Amendment provides the technical rationale for amending the original ROD (signed September 29, 1994). The remedial alternatives were selected in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The information supporting the decisions on the selected remedies is contained in the Administrative Record.

The United States Environmental Protection Agency (USEPA) Region VII and the Nebraska Department of Environmental Quality (NDEQ) concur with the selected remedy.

ASSESSMENT OF THE SITE

The current and realistic future land use for OU1 is industrial and agricultural. The response actions selected in this ROD Amendment for OU1 are necessary to protect the public health and welfare from actual or threatened releases of hazardous substances into the environment. The remedies for OU1 are not driven by ecological risks because the areas that comprise OU1 have no completed exposure pathways for ecoreceptors.

DESCRIPTION OF THE NEW PROPOSED REMEDY

The new Proposed Remedy presents a significant and fundamental change to the original Selected Remedy. The new Proposed Remedy includes the addition of a seventh extraction well to the on-post groundwater extraction system and the implementation of monitored natural attenuation for the off-post distal plume. The monitored natural attenuation alternative replaces off-post extraction and treatment originally planned for the distal plume. The Remedial Action Objectives (RAOs) for OU1 are the same as those listed in the original ROD which were based on the USEPA Health Advisory Levels for explosives.

The new Proposed Remedy also includes institutional controls to prevent residential use for off-post groundwater (in the form of a City Ordinance) and on-post groundwater (in the form of deed restrictions). The U.S. Army will be responsible for implementing and maintaining the effectiveness of institutional controls.

STATUTORY DETERMINATIONS

The new Proposed Remedy will protect human health and the environment, comply with Federal and state requirements that are applicable or relevant to the remedial action, is cost effective, and

Declaration of the Record of Decision Amendment

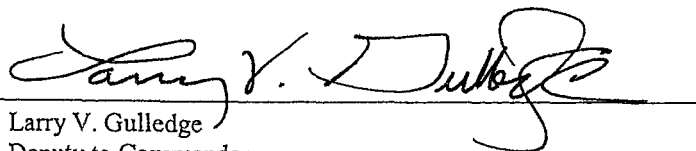
utilizes permanent solutions. Both the on-post and off-post portions of the plume will be treated until the RAOs for OU1 are achieved.

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after initiation of remedial action to ensure that the remedy is, or will be, protective of human health.

ROD DATA CERTIFICATION CHECKLIST

The following information is included in this ROD Amendment. Additional information can be found in the Administrative Record file for this site.

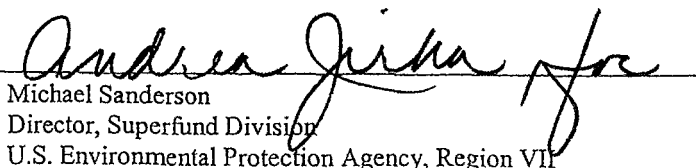
- Chemicals of potential concern (COPCs) (Section 2)
- Baseline risk represented by the COPCs (Section 2)
- Cleanup levels established for COPCs and the basis for these levels (Section 2)
- How source materials constituting principal threats are addressed (Section 4)
- Current and reasonably anticipated future land use assumptions used in the baseline risk assessment and ROD (Sections 2 and 4)
- Potential land use that will be available at the site as a result of the Selected Remedies (Section 4)
- Estimated capital, annual operation and maintenance (O&M), and total present value costs, and the number of years over which the remedy cost estimates are projected (Section 5)
- Key factors that led to selecting the remedies (Section 5)



Larry V. Gullledge
Deputy to Commander
U.S. Army Operations Support Command

7 Sep. 2001

Date



Michael Sanderson
Director, Superfund Division
U.S. Environmental Protection Agency, Region VII

9/26/01

Date

This Record of Decision (ROD) Amendment for Operable Unit One (OU1) identifies the new Proposed Remedy for remediating groundwater at OU1 of the Cornhusker Army Ammunition Plant (CHAAP), Grand Island, Nebraska (see **Figure 1**). The ROD Amendment provides the rationale for amending the original ROD (signed on September 29, 1994). This document is issued by the US Army, the owner of the site, with concurrence from the U.S. Environmental Protection Agency Region VII (USEPA) and the Nebraska Department of Environmental Quality (NDEQ).

The US Army is choosing to implement the new Proposed Remedy presented in this ROD Amendment in accordance with Section 117 of the Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and to the extent practicable, Section 300.435(c)(2)(ii) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This ROD Amendment summarizes information that is presented in greater detail in the original ROD (signed on September 29, 1994), Remedial Investigation/Feasibility Study (ICF Kaiser 1996) and subsequent groundwater monitoring reports (W-C 1997, 1998a, 1999; URSGWFS 1999; URS 2000b). All documents are included in the Administrative Record File for this site (in accordance with Section 300.825(a)(2) of the NCP).

The ROD Amendment will become part of the Administrative Record file. The Administrative Record file, which includes all documents referenced in this ROD Amendment (in accordance with Section 300.825(a)(2) of the NCP), is available for public review at the Grand Island Public Library. USEPA and the NDEQ encourage the public to review these documents to gain a more comprehensive understanding of site remediation activities.

The Administrative Record File, including all referenced documents, for the site is available at:

Grand Island Public Library
211 North Washington Street
Grand Island, Nebraska 68802
(308) 385-5333

Hours of operation:

M-Th 9 a.m. – 9 p.m.
Fr-Sat 9 a.m. – 9 p.m.
Sat 1 p.m. – 5 p.m.

SECTION TWO Site History, Contamination, and Original Selected Remedy

CHAAP is located on a 10,520-acre tract approximately 2 miles west of Grand Island, Nebraska (see **Figure 1**). CHAAP was constructed and became fully operational in 1942 as a U.S. Government-owned, contractor-operated facility. CHAAP was responsible for the production of artillery shells, mines, bombs, and rockets for World War II and the Korean and Vietnam conflicts. The plant was operated intermittently for 30 years, with the most recent operations ending in 1973. The facility is currently in the process of being excessed in accordance with the Hall County reuse plan.

CHAAP was placed on the Superfund National Priorities List (NPL) in 1987 and is participating in the Installation Restoration Program (IRP), a specially funded program established by the Department of Defense (DoD) in 1978 to identify, investigate, and control migration of hazardous contaminants at DoD facilities. An Interagency Agreement between the USEPA, NDEQ, and the DoD was signed in 1990, under which the US Army has investigated and is cleaning up the site.

2.1 CONTAMINATION

Explosive wastes and residues associated with munitions loading, assembly, and packing operations resulted in a groundwater contamination plume that originated near the CHAAP load lines and extends northeastward towards Grand Island (see **Figures 2 and 3**).

The explosive compounds have migrated east-northeast with the predominant direction of groundwater flow. The more mobile compounds, RDX and HMX, have migrated the greatest distances. Highly sorbing compounds, such as TNT, have migrated shorter distances.

Evaluation and remediation of explosives contamination has been an ongoing process at CHAAP. The US Army conducted a soil excavation and incineration project from 1987 to 1988 designed to remove the soil sources of explosives contamination. That project reduced the soil contamination source areas; however, high concentrations of dissolved contaminants remained in groundwater.

2.2 SUMMARY OF SITE RISK ASSESSMENT

The Remedial Investigation/Feasibility Study (RI/FS) report (ICF Kaiser 1996) included a risk assessment to estimate current and future risks to human health and the environment from exposures to contaminated groundwater. Although the levels of explosives in on-post groundwater were elevated, there are many uncertainties in predicting the risk estimates, including the assumption that residents would actually consume on-post groundwater on a regular basis.

Estimated risks for carcinogens (potentially cancer-causing chemicals) were compared to the NCP acceptable range (e.g., the target risk range of one in a million to one in ten thousand [1×10^{-6} to 1×10^{-4}] for human health protection at Superfund sites). Chemicals with completed pathways that exceed a risk of one in one million (1×10^{-6}) usually warrant remedial action under Nebraska ARARs.

Noncarcinogen chemical concentrations were compared to a hazard quotient of 1.0. Chemicals that are present in concentrations that exceed a hazard quotient of 1.0 usually warrant remedial action. Estimated risks are summarized as follows.

2.2.1 Estimated On-Post Groundwater Risks

- For ingestion of explosives-contaminated on-post groundwater, the risk estimates indicated excess lifetime cancer risks above the 1×10^{-4} risk level. In addition, it was determined that unacceptable levels of adverse noncarcinogenic effects associated with explosives in groundwater may occur. This exposure pathway will be eliminated because CHAAP will implement deed restrictions prohibiting drinking water supply wells on excessed property in the vicinity of the plume.
- Future cancer risk estimates associated with the future ingestion of crops irrigated with on-post groundwater were at the low end of the 1×10^{-6} to 1×10^{-4} risk range, and the noncarcinogenic hazard indices were below one. These low risk estimates demonstrate, based on the assumptions made in the risk assessment, that no unacceptable cancer risks and no unacceptable adverse health effects are likely to occur from exposure to explosives in vegetables that have been irrigated with CHAAP groundwater.
- There are no estimated risks to ecological receptors because on-post groundwater is considered inaccessible to ecological receptors at CHAAP.
- Risks associated with all other organic and inorganic chemicals in groundwater were estimated to be at acceptable levels.

2.2.2 Estimated Off-Post Groundwater Risks

- Lifetime groundwater risk estimates for off-post residents were all lower than or at the low end of the 1×10^{-6} to 1×10^{-4} risk range and all hazard indices were less than one, except for a child's ingestion of groundwater. The need for groundwater use as a drinking water supply has been eliminated because all residences in the affected areas have been connected to the city water supply.
- There are no estimated risks to ecological receptors because off-post groundwater is considered inaccessible to ecological receptors near CHAAP and in the city.

2.3 REMEDIAL ACTION OBJECTIVES

The Remedial Action Objectives for CHAAP groundwater are:

- Protect human health and the environment
- Clean up groundwater to below health advisory levels
- Contain high concentrations of explosives in groundwater on post

The ROD (USAEC 1994b) established Remedial Action Objectives for explosives in groundwater at CHAAP. The Remedial Action Objectives are included on Table 1 and remain unchanged for the new Proposed Remedy.

2.4 ORIGINAL SELECTED REMEDY

2.4.1 Original Selected Remedy On Post

Under terms of the first ROD, signed on September 29, 1994, the original Selected Remedy in the area identified as the contamination source (e.g., on post) included:

- Extraction of contaminated groundwater;
- Treatment of the extracted groundwater using granular activated carbon (explosives), granular media filtration (suspended solids), chemical precipitation (as needed to meet NPDES limits), and the constructed wetlands (nitrates);
- Discharge of treated effluent to the Platte River through the Wood River Diversion Channel easement.

The on-post portion of the groundwater extraction and treatment system was constructed in summer 1998 under the direction of the US Army Corps of Engineers (USACE). Full-time operation began in December 1998. The original groundwater extraction system included six wells with a total extraction flow rate of about 750 gallons per minute.

In March 2000, an additional extraction well was added to improve the on-post extraction system. The on-post extraction system is designed to prevent the migration off post of the on-post portion of the explosives plume (i.e., highest explosives concentrations). The overall flow rate was maintained at 750 gallons per minute. Groundwater is currently being treated for explosives through granular activated carbon filters and discharged to on-post drainage canals leading to Silver Creek.

2.4.2 Original Selected Remedy Off Post

The original Selected Remedy for the area identified as the distal end/intermediate area included:

- Extraction of contaminated groundwater at both the distal end and the intermediate area;
- Treatment of the extracted groundwater using granular activated carbon and granular media filtration;
- Discharge of treated effluent to the Platte River through the Wood River Diversion Channel easement.

The off-post portion of the groundwater extraction and piping system (that is, the distal end/intermediate area remedy) was tabled due to difficulties with establishment of permanent easements for the piping and public concern for any additional effluent discharges to Silver Creek.

The technical basis for the ROD Amendment is the Long-Term Monitoring data, the results of the Monitored Natural Attenuation Demonstration, and the model-predicted contaminant fate and transport.

3.1 LONG-TERM MONITORING AND NATURAL ATTENUATION DEMONSTRATION

The primary objective of the LTM program was to monitor and identify explosives plume migration trends in the off-post monitoring well locations. Additional objectives for the LTM included identifying natural attenuation trends for the off-post explosives plume. Five LTM and natural attenuation demonstration sampling events have been completed since 1998. The data from these events supports the use of monitored natural attenuation for remediation of the off-post explosives plume. Complete discussion of the natural attenuation demonstration methodology, water quality parameter results, natural attenuation processes identification, and degradation rate estimates along with supporting tables and figures is included in **Appendix B**.

3.1.1 Long-Term Monitoring Results

The LTM sampling results support the following conclusions:

Off-Post Plume

- The explosives plume, consisting primarily of RDX, is still present off post, but has not migrated any further downgradient.
- Explosives concentrations within the off-post plume have declined over time from 1994 to 2000.
- TNT breakdown products (e.g., 2-Am-DNT and 4-Am-DNT) have been detected in off-post monitoring well clusters NW020, CA350, and CA380, indicating biodegradation has occurred.
- HMX has not been detected above the health advisory level (i.e., 400 µg/L) during any LTM sampling event.

Reasons for off-post explosives concentrations declining from 1984 (Spalding and Fulton 1988) to 2000 (URS 2000) include natural attenuation processes (e.g., dispersion, biodegradation, and abiotic degradation), contaminant soil source removal and on-post groundwater extraction.

On-Post Source Areas

- RDX and TNT concentrations remain significantly above health advisory levels at LL1, LL2, and LL3.
- On-post RDX and TNT concentrations near extraction wells EW-4, EW-5, and EW-6 have remained low (similar over the past three LTM monitoring events).
- No explosives concentrations were detected above health advisory levels at LL4, LL5, or the nitrate area.

- HMX has not been detected above the health advisory level (i.e., 400 µg/L) during any LTM sampling event.

Complete discussion of the current nature and extent of the explosives plume, along with supporting table and figures, is included in **Appendix B**.

3.1.2 Natural Attenuation Demonstration Results

The natural attenuation demonstration results indicated natural attenuation of explosives in groundwater is occurring at CHAAP. The key elements that support the use of monitored natural attenuation at CHAAP include:

- RDX and TNT concentrations in the off-post plume have decreased steadily over time.
- Significant denitrification is occurring in the feedlot area, which is facilitating explosives degradation as the plume migrates through this area. The feedlot area subsurface zone is functioning as an in-situ anaerobic/reducing treatment cell.
- Other anaerobic degradation processes (e.g., Fe reduction, methanogenesis, and sulfate reduction) are also occurring in the feedlot area, but to a lesser extent.
- Explosives degradation products are present, including RDX degradation products (e.g., MNX, DNX, and TNX [Spalding 1998]) and TNT breakdown products (e.g., 2-Am-DNT and 4-Am-DNT). The degradation products have not been detected at concentrations above 1×10^{-6} risk levels and will continue to be monitored under the long-term monitoring program.
- Contaminant fate and transport modeling results indicate the off-post explosives plume is degrading at a sufficient rate to achieve cleanup goals within a timeframe that is approximately equal to the expected time frame for remediation to be completed using an off-post pump-and-treat remedy (e.g., 10 to 15 years for distal plume).
- The on-post explosives soil source areas have been removed.
- No further migration of on-post explosives contamination is expected because contaminated groundwater migration from groundwater explosives source areas will be contained by the on-post groundwater extraction system.
- Potential off-post receptors/residences have been provided an alternative drinking water source (i.e., connected to Grand Island city water supply).

3.2 GROUNDWATER FLOW AND CONTAMINANT FATE AND TRANSPORT MODELING

A numerical groundwater contaminant fate and transport model was developed to evaluate the use of natural attenuation for remediation of the off-post explosives. The numerical model simulated baseline contaminant transport and transport under remediation conditions. The baseline contaminant fate and transport simulation and the new Proposed Remedy simulation were used to evaluate natural attenuation of the off-post explosives plume. Complete details of

Model-predicted results indicated on-post pumping could contain the existing explosives plume on the facility property while the off-post plume is allowed to naturally attenuate. Model-predicted results indicated the off-post plume would naturally attenuate to below target clean-up goals in about 20 years.

3.2.4 Contaminant Fate and Transport Modeling Conclusions

Contaminant fate and transport modeling of extraction alternatives indicated the optimized on-post extraction with EW-7 and off-post natural attenuation alternative (i.e., the new Proposed Remedy) would remove contamination emanating from LL 1, 2, and 3, contain the on-post contamination, and naturally attenuate the off-post plume. Model-predicted results indicated distal extraction would not decrease the overall clean-up times significantly.

This ROD Amendment presents a significant and fundamental modification to the original Selected Remedy. This modification includes the addition of a seventh extraction well (EW-7) to the on-post groundwater extraction system and the implementation of monitored natural attenuation for the off-post distal plume. The monitored natural attenuation alternative replaces off-post extraction and treatment originally planned for the distal plume.

The full set of remedial alternatives to treat on- and off-post groundwater at CHAAP were presented in the Feasibility Study (WJE 1994), analyzed in the original Proposed Plan (USAEC 1994a), and modified in the Explanation of Significant Differences (USAEC 1996), and will not be restated herein. Instead, this document will focus on the original Selected Remedy compared to the new Proposed Remedy.

4.1 SUMMARY OF REMEDIES

Table 2 summarizes the original Selected Remedy and the new Proposed Remedy. The original Selected Remedy and the new Proposed Remedy are shown on **Figures 4 and 5**, respectively.

4.1.1 Original Selected Remedy Summary

The original Selected Remedy included the following basic components:

- On-post groundwater extraction
- Off-post groundwater extraction
- Groundwater Treatment
- Disposal of treated water to Silver Creek
- Institutional controls designed to limit public exposure to contaminated groundwater

A portion of the original Selected Remedy is currently in place without the off-post groundwater extraction wells and a change in discharge location.

4.1.2 New Proposed Remedy Summary

The new Proposed Remedy includes the following basic components:

- On-post groundwater extraction and treatment (completed December 1998) using optimized extraction rates and an additional extraction well (completed March 2000)
- Disposal of treated water to Silver Creek
- Monitored natural attenuation of the off-post plume
- Institutional controls designed to limit public exposure to contaminated groundwater on and off post

The new Proposed Remedy has several advantages over the original Selected Remedy. The new Proposed Remedy is expected to reduce capital costs by at least \$4.0 million compared to the

original Selected Remedy while achieving substantial risk reduction through the permanent treatment of groundwater contaminants using natural processes.

The new Proposed Remedy is also expected to reduce the risk within a time frame similar to that expected with the original Selected Remedy. Based on the information available at this time, the US Army believes the new Proposed Remedy is protective of human health and the environment, complies with Applicable or Relevant and Appropriate Requirements (ARARs), is cost-effective, and utilizes permanent solutions to the maximum extent practicable. Because it would continue to treat the groundwater sources constituting principal threats, the new Proposed Remedy also would meet the statutory preference for the selection of a remedy that involves treatment as a principal element.

4.2 TREATMENT, CONTAINMENT, AND STORAGE COMPONENTS

The treatment, containment, and storage components of the original Selected Remedy and the new Proposed Remedy are outlined on **Table 2** and summarized in the following sections.

4.2.1 Original Selected Remedy Treatment, Containment, and Storage Components

The original Selected Remedy included the operation of an on-post groundwater extraction and treatment system comprised of six extraction wells. This system has been modified to include continued operation of the on-post groundwater extraction and treatment system with the addition of a seventh extraction well (installed in March 2000), which has been designated EW-7. EW-7 was constructed along the mid-line of the explosives plume adjacent to the downgradient (i.e., eastern) Post boundary to provide on-post containment of the explosives plume.

Extracted groundwater is piped to a central groundwater treatment facility. Groundwater is pre-treated (for suspended solids removal) using granular media filters, treated for explosives using granular activated carbon, discharged to on-post drainage canals leading to Silver Creek, and ultimately discharged to Silver Creek. There is no storage component to the original Selected Remedy.

In addition, the original Selected Remedy included the operation of an off-post extraction system (and augmented treatment facility) originally planned for the distal end and intermediate area of the plume. The off-post extraction system was originally planned to prevent further migration of explosives by containing the distal end of the plume. Administrative implementability constraints delayed the construction of the off-post extraction system.

4.2.2 New Proposed Remedy Treatment, Containment, and Storage Components

The new Proposed Remedy modifications include the addition of EW-7 to provide containment of the on-post explosives plume combined with the elimination of the off-post extraction wells, conveyance piping, and augmented treatment system. Instead, off-post groundwater will be monitored while the low concentrations of explosives naturally attenuate.

Two distinct lines of evidence support the monitored natural attenuation component of the new Proposed Remedy. Supporting evidence includes demonstrated trends of declining explosive concentrations and total mass over time and predictive computer modeling (documented in the March 2000 LTM report (URS 2000b) and Groundwater Flow and Contaminant Fate and Transport Modeling report [URS 2001]).

Monitored natural attenuation will be implemented in accordance with a Long-Term Monitoring Plan developed for the CHAAP site. The Long-Term Monitoring Plan will include appropriate monitoring well locations, field analyses, laboratory analyses, schedules, and reporting requirements. The Long-Term Monitoring Plan will be based on the original Technical Plan for the Long-Term Monitoring Program (W-C 1997) and the subsequent annual Amendments (W-C 1998, URSGWCFS 1999, and URSGWCFS 2000a). The objective of the long-term monitoring program will be to monitor explosives concentrations and migration trends for the on-post and off-post portions of the plume.

This new Proposed Remedy will ensure that the toxicity, mobility and volume of the contaminants in the on- and off-post groundwater are permanently reduced to acceptable levels (i.e., Remedial Action Objectives). All contaminants will be treated under the new Proposed Remedy; no hazardous materials or wastes will be contained or stored.

4.3 INSTITUTIONAL CONTROL COMPONENTS

The original Selected Remedy included limited provisions for institutional controls. These institutional controls will be augmented under the new Proposed Remedy. The additional institutional controls are designed to help prevent drinking water exposures to contaminated groundwater until the Remedial Action Objectives (listed in **Table 1**) have been attained throughout the plume area.

Institutional controls for both the original Selected Remedy and the new Proposed Remedy are listed below.

4.3.1 Institutional Controls/Actions for Original Selected Remedy

The original Selected Remedy included the following institutional controls/actions:

- Off-Post Plume
 - The US Army contracted the City of Grand Island to extend, in 1986 and 1993, the municipal water main to provide water supply to all residences (est. 400) in the vicinity of the plume. Five residences refused the City water hookup at that time. Those five residences are currently outside the interpreted explosives plume boundary (drawn using Health Advisory Levels (USEPA 2000)) presented in the March 2000 Long Term Monitoring Report (URS 2000).
 - The US Army has communicated plume locations, concentrations, and drinking water hazards to the public through Public Meetings and Press Releases in Grand Island Paper.

- **On-Post Plume**

- The US Army prohibits water supply (drinking and irrigation) well drilling in the on-post plume area.

4.3.2 Institutional Controls/Actions for New Proposed Remedy

The new Proposed Remedy includes the following institutional controls/actions:

- **Off-Post Plume**

- The US Army will assist the City in establishing a City “Overlay Zone” Ordinance for an institutional control area prohibiting drinking water supply well drilling in the plume area. The City will monitor and enforce the Ordinance by denying plumbing permits to hookup residences to private wells in the “Overlay Zone”.
- The City of Grand Island will continue to provide water supply to all residences in the plume area.
- The US Army will continue to communicate plume locations, concentrations, and drinking water hazards to the public through Press Releases in the Grand Island Independent newspaper. The paper will be notified when the annual monitoring report is issued at the conclusion of each annual sampling round.

- **On-Post Plume**

- Land use restrictions will be placed on excessed property. The land use restrictions will include: 1) Restrictive covenants or easements prohibiting drinking water supply well drilling in the plume vicinity until groundwater is cleaned up to health advisory levels, and 2) Restrictive covenants or easements prohibiting the use of the property for residential purposes.
- The Hall County Reuse Plan will enforce excessed CHAAP land designation for agricultural and industrial zoning.
- For US Army property, water supply well drilling will continue to be prohibited in the plume area.

The US Army will monitor the effectiveness of the institutional controls. The US Army will include institutional control results in the Annual Long-Term Monitoring Reports for the CHAAP facility.

4.4 KEY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

All ARARs potentially considered are listed in Section 3 of the Focused Feasibility Study (WJE 1994). The requirements determined to be Applicable or Relevant and Appropriate are listed in **Table 2** through **4**, which include chemical-specific, location-specific, and action-specific ARARs. In the absence of chemical-specific ARARs for explosives, USEPA health advisory levels (USEPA 2000) are used for determining the remedial action objectives.

4.5 REMEDIAL ACTION OBJECTIVES

As discussed above, the same Remedial Action Objectives (see **Table 1** and Section 2.3) will be used under the new Proposed Remedy as the original Selected Remedy. The Remedial Action Objectives include the USEPA health advisory levels as clean-up goals for explosives in groundwater (USEPA 2000). The time required to achieve the objectives under the new Proposed Remedy is not anticipated to be any longer than under the original Selected Remedy (URS 2000).

4.6 EXPECTED OUTCOMES

Aside from the implementation of additional institutional controls (discussed above), there are no changes to the expected outcomes that will result from this ROD Amendment.

This section discusses the relative performance of the original Selected Remedy versus the new Proposed Remedy. Nine criteria are typically used to evaluate different scenarios and select a remedy. **Table 5** provides a comparison of the original Selected Remedy and the new Proposed Remedy using these nine evaluation criteria. The comparison is summarized below.

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Both remedies will provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk. Under the original Selected Remedy, explosives will be treated to Remedial Action Objectives, both on and off post, using extraction and treatment technologies.

Under the new Proposed Remedy, on-post explosives will be treated to Remedial Action Objectives using extraction and treatment technologies. However, the off-post explosives will be treated through natural attenuation mechanisms.

Both demonstrated trends of declining explosives concentrations and total mass, and predictive computer modeling indicate that monitored natural attenuation of the off-post explosives plume would successfully attain Remedial Action Objectives. The USEPA and NDEQ have determined that contingency measures are not warranted as part of the new Proposed Remedy.

The estimated time for monitored natural attenuation to attain Remedial Action Objectives off post is the same as the original Selected Remedy using extraction and treatment technologies.

5.2 COMPLIANCE WITH ARARS

Both groundwater remedial remedies would meet all ARARs with respect to Federal and State laws. ARARs are included in **Tables 3 and 4**.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Both groundwater remedies would be effective in the long term by reducing contaminant concentrations in groundwater. The adequacy and reliability of the extraction and treatment technologies have been well proven for explosives. Monitored natural attenuation has some uncertainty associated with the time required to reach the final Remedial Action Objectives, but the predictive modeling results (URS 2001) estimated cleanup times to be similar to the current alternative.

5.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME OF CONTAMINANTS THROUGH TREATMENT

The original Selected Remedy uses extraction and treatment with carbon adsorption to reduce toxicity, mobility, and volume of contaminants. Spent carbon units containing explosives

residuals are being regenerated prior to thermal destruction and managed in accordance with the Resource Conservation and Recovery Act (RCRA).

The new Proposed Remedy uses natural processes to reduce toxicity, mobility, and volume of contaminants in off-post groundwater.

5.5 SHORT-TERM EFFECTIVENESS

Precautions were taken during construction of the extraction wells under the original Selected Remedy to eliminate all risks to the public associated with construction. Short-term risks to construction workers associated with normal construction hazards and potential contact with contaminated water were eliminated through appropriate controls and adherence to proper health and safety protocols.

The new Proposed Remedy has no new risks associated with implementation, would take little to no time to implement, and is anticipated to be effective in the short-term.

5.6 IMPLEMENTABILITY

Both groundwater remedies are technically implementable without construction difficulties.

The off-post portion of the original Selected Remedy had significant administrative difficulties and has not been implemented. Administrative concerns have included difficulties in gaining access agreements and easements for the 7.5 miles of off-post piping to be installed, and difficulties in gaining public consensus to discharge an additional 750 to 1,500 gallons per minute to Silver Creek. Any increase in discharge that will impact the downstream drainage of Silver Creek will require the US Army to relocate the effluent discharge.

The new Proposed Remedy has few associated administrative difficulties and requires little or no implementation time.

5.7 COST

The estimated capital cost of the new Proposed Remedy is slightly more than that of the original Selected Remedy for the on-post groundwater (due to the construction and operation of a seventh extraction well), but significantly less than that of the original Selected Remedy for the off-post groundwater. The estimated capital cost of the original Selected Remedy is \$9.0 million for the on-post groundwater remedy, and \$4.0 million for the off-post groundwater remedy. In contrast, the estimated capital cost of the new Proposed Remedy is \$9.7 million for the on-post groundwater remedy (including the addition of a seventh extraction well), and \$0 for the off-post groundwater remedy.

Both remedies were estimated to take a similar amount of time to achieve cleanup goals. Estimated cost for groundwater monitoring and operation and maintenance (O&M) of the treatment system for the original Selected Remedy is \$1.2 million per year, versus \$800 thousand

per year for the new Proposed Remedy. These annual costs were used to estimate both a present value and a total incremental cost of each remedy. Costs are summarized in the table below.

SUMMARY OF ESTIMATED OU1 REMEDIAL COSTS

Costs	Original Selected Remedy	New Proposed Remedy
On-Post Capital Costs	\$9 M	\$9.7 M
Off-Post Capital Costs	\$4 M	\$0
Annual Operation and Maintenance Costs	\$1.2 M	\$0.8 M
Presents Value (20-years at 7%)	\$26 M	\$18 M
Total Incremental Costs (20-years)	\$36 M	\$26 M

5.8 STATE/SUPPORT AGENCY ACCEPTANCE

The USEPA and NDEQ support the new Proposed Remedy and believe the combination of on-post groundwater extraction and off-post monitored natural attenuation will lead to restoration of the aquifer to the proposed health advisory levels in an acceptable time frame. The USEPA and the NDEQ also believe the institutional controls will minimize the threat of human exposure to groundwater contamination before complete aquifer restoration is achieved. The USEPA and the NDEQ will monitor the effectiveness of the proposed remedies to ensure that they remain protective of human health and the environment.

5.9 COMMUNITY ACCEPTANCE

Community acceptance of the new Proposed Remedy will be evaluated after the public comment period ends and will be described in the forthcoming Final CHAAP OU1 ROD Amendment.

This section includes all support agency comments on the ROD Amendment and subsequent US Army responses and resolutions.

6.1 USEPA REGION VII COMMENTS AND US ARMY RESPONSES /RESOLUTIONS

Comments by Robert Koke, USEPA Region VII, dated April 23, 2001:

Comment 1. Page 2-3, Section 2.4.1, paragraph 3. End the first sentence at system. Add the following to the next sentence. *The on-post extraction system is design[ed] to prevent the migration off post of the on-post...*

Comment 2. Page 3-1, first paragraph. Make this *change ...natural attenuation for remediation of the off-post...*

Comment 3. Page 3-2, Section 3.1.2, bullet 5. Cleanup goals within a time frame that is approximately equal to the expected time frame for remediation to be completed using an off-post... Bullet 7 ...expected because contaminated groundwater migration from groundwater explosives... contained by the on-post...

Comment 4. Section 3.2. Rewrite the first sentence: *A numerical groundwater contaminant fate and transport model was developed to evaluate the use of natural attenuation for remediation of the off-post explosives.*

Comment 5. Section 3.2.1, first sentence. *Explosive concentrations and plume area interpreted from the March...*

Comment 6. Section 3.2.3, first paragraph, last sentence. *...extraction rate with the additional well...*

Comment 7. Page 4-3, second sentence. Insert a comma after over time. Second paragraph, second sentence. Change *frequency* to *schedules*.

Comment 8. Section 4.3.1, first dash. Move *in 1986 and 1993* to after the word “extend”.

Comment 9. Section 5.1, paragraph 3. Start: Both demonstrated trends... Comma after mass. Eliminate the words between modeling and indicate.

Comment 10. Section 5.3, last sentence. *...associated with the amount of time required. Change estimated to estimate.*

Comment 11. Section 5.5. Insert *new* between *no risks* in last paragraph.

Comment 12. Section 5.6, second paragraph, second sentence. *Consensus to discharge of an additional...*

Comment 13. Tables 2 and 3 *and /Actions* after institutional controls. Also providing water supply is not an institutional control. It is a remedial action.

US Army Response/Resolution: Comments noted. Changes will be incorporated into the Final OU1 ROD Amendment.

6.2 NEBRASKA DEPARTMENT OF ENVIRONMENTAL QUALITY COMMENTS AND US ARMY RESPONSES/RESOLUTIONS

Comments by Edward W. Southwick, P.G., NDEQ Remediation Section, Waste Mgmt. Div., dated May 29, 2001:

Comment 1. ISSUE: Type of Record of Decision (ROD). The 1994 ROD was an Interim Action ROD. Since this ROD amends the 1994 ROD, is it still an interim action ROD that should instead be entitled “Interim Action OU1 ROD Amendment?” Or does this amendment, in addition to modifying the 1994 ROD, also finalize it and thereby remove the “Interim Action” label? Please clarify. Also, should not Section 1 also include an explanation?

US Army Response/Resolution: EPA Region VII’s position is that the term “Interim ROD” will no longer be used. EPA Region VII recommends that the document be titled “OU1 ROD Amendment”.

Comment 2. REFERENCE: Section 2.2, 2nd Paragraph, Last Sentence. This sentence, stating that remedial action is usually required for chemicals exceeding 1×10^{-4} risk levels, fails to acknowledge that Nebraska ARARs requires cleanup to considerably stricter standards, MCLs or 1×10^{-6} cumulative excess cancer risk level. NDEQ recommends modifying the last sentence or adding a new one which informs the reader that remedial action to MCLs or 1×10^{-6} risk levels is required under Nebraska ARARs.

US Army Response/Resolution: We will revise the last sentence in the second paragraph to read ...”Chemicals with completed pathways that exceed a risk of one in one million (1×10^{-6}) usually warrant remedial action under Nebraska ARARs.

Comment 3. ISSUE: Contaminants of Concern. This ROD proposes remediation of only three chemicals of concern (COCs) – TNT, HMX, and RDX – even though other potential COC’s have been found in on-post and off-post groundwater. NDEQ wants to know if correspondence exists that address other COC’s, particularly those with estimated exposure pathways exceeding 1×10^{-6} risk levels (i.e. on-post VOCs). With regard to other explosive compounds (see fourth bullet of Section 3.1.2), NDEQ recommends including a statement that these contaminants (to date) have not been detected above 1×10^{-6} risk levels and will continue to be monitored under the long-term monitoring program.

US Army Response/Resolution: Currently, there are no on-post VOCs exceeding 1×10^{-6} or MCLs associated with the OU1 groundwater. There were on-post VOCs associated with OU3 that exceeded MCLs. These have been addressed under the OU3 ROD.

US Army Response/Resolution: A sentence will be added under Section 3.1.2, fourth bullet, that will read...”The degradation products have not been detected at concentrations above 1×10^{-6} risk levels and will continue to be monitored under the long term monitoring program.”

Under Section 121 of CERCLA and the NCP, the lead regulatory agency must select remedies that are protective of human health and the environment, comply with ARARs (unless a statutory waiver is justified), are cost-effective, and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment to permanently and significantly reduce the volume, toxicity, or mobility of hazardous wastes as a principal element. CERCLA also includes a bias against off-site disposal of untreated wastes. The following sections discuss how the new Proposed Remedy meets these statutory requirements.

7.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The new Proposed Remedy will protect human health and the environment through the treatment of on-post explosives contamination using extraction and treatment technologies. In addition, off-post contamination will be monitored as it attenuates naturally. Both the on-post and the off-post portions of the plume will be treated until the groundwater Remedial Action Objectives have been attained.

The new Proposed Remedy will reduce the cancer risks from exposure to less than 1×10^{-6} and the Hazard Index for adverse, noncarcinogenic health effects to less than 1.0. This level falls below USEPA's target risk range of 1×10^{-6} to 1×10^{-4} . There are no short-term threats associated with the new Proposed Remedy that cannot be readily controlled. In addition, no adverse cross-media impacts are expected from the new Proposed Remedy.

7.2 COMPLIANCE WITH ARARS

The new Proposed Remedy including an on-post extraction and treatment system and monitored natural attenuation off-post complies with all ARARs. The ARARs are presented above in **Tables 2** through **4**.

7.3 OTHER CRITERIA, ADVISORIES, OR GUIDANCE TO BE CONSIDERED (TBCS) FOR THIS REMEDIAL ACTION

In implementing the new Proposed Remedy, the USEPA and the State have agreed to consider a number of non-binding criteria, also known as TBCs. The Monitored Natural Attenuation Demonstration (URS 2000) and subsequent recommendation of monitored natural attenuation of the off-post explosives plume was completed in accordance with TBC protocols presented in:

- United States Environmental Agency. 1997. "Use of Monitored Natural Attenuation at Superfund, RCRA, Corrective Action, and Underground Storage Tank Sites." OSWER Directive 9200.4-17. December 1.
- United States Army Corps of Engineers Waterways Experiment Station. 1999. "Draft Protocol for Evaluating, Selecting, and Implementing Monitored Natural Attenuation at Explosives-Contaminated Sites." Technical Report EL-99. March.

7.4 COST-EFFECTIVENESS

The USEPA believes the new Proposed Remedy is cost-effective and represents a reasonable value for the money to be spent. In making this determination, the following definition was used: “A remedy shall be cost-effective if its costs are proportional to its overall effectiveness,” (NCP §300.430(f)(1)(ii)(D)). This was accomplished by comparing the costs associated with the original Selected Remedy to the costs associated with the new Proposed Remedy since the “overall effectiveness” of both remedies satisfied the threshold criteria (i.e., both were protective of human health and the environment and ARAR-compliant). Overall effectiveness was determined by assessing three of the five balancing criteria in combination (long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness).

The estimated present worth cost of the new Proposed Remedy is \$26 million (based on a 20-year evaluation at a 7-percent discount rate). Although this cost includes a \$700,000 capital cost increase to the on-post portion of the remedy (due to the installation and operation of the seventh extraction well), the significant decrease in off-post capital costs (\$0 for the new Proposed Remedy, versus \$4.0 million for the original Selected Remedy) compensates for this additional initial cost. The total cost savings estimated from the new Proposed Remedy, based on total incremental costs over 20 years, is \$11 million. USEPA believes that the new Proposed Remedy will provide an overall level of protection to human health and the environment comparable to the original Selected Remedy at a significantly lower cost.

7.5 UTILIZATION OF PERMANENT SOLUTIONS AND ALTERNATIVE TREATMENT TECHNOLOGIES (OR RESOURCE RECOVERY TECHNOLOGIES) TO THE MAXIMUM EXTENT PRACTICABLE

The USEPA has determined the new Proposed Remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the site.

The new Proposed Remedy treats the source materials constituting principal threats at the site to achieve significant reductions in explosives concentrations. The new Proposed Remedy also satisfies the criteria for long-term effectiveness by permanently eliminating the explosives contamination through natural means. The new Proposed Remedy does not present short-term risks different from the other treatment alternatives. There are no special implementability issues associated with the new Proposed Remedy.

7.6 PREFERENCE FOR TREATMENT AS A PRINCIPAL ELEMENT

By treating site contamination using extraction and treatment technologies combined with monitored natural attenuation, the new Proposed Remedy addresses principal threats posed by the site through the use of treatment technologies. This satisfies the statutory preference for remedies that employ treatment as a principal element.

7.7 FIVE-YEAR REVIEW REQUIREMENTS

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site until Remedial Action Objectives have been attained, a statutory review will be conducted within five years after initiation of new Proposed Remedy to ensure that the remedy will remain protective of human health and the environment.

The US Army, USEPA, and NDEQ have solicited input from the community on the ROD Amendment for cleanup of the CHAAP site. At this time, there have been no oral or written comments from the public on the Revised Proposed Plan for OU1 ROD Amendment.

Community participation has complied with the following in accordance with the NCP Section 300.515e. The US Army and regulatory agencies:

- Have issued a notice of availability and brief description of the proposed amendment to the ROD in a major local newspaper of general circulation;
- Have made the revised proposed plan for the amendment to the ROD and information supporting the decision available for public comment;
- Have provided a reasonable opportunity, not less than 30 calendar days, for submission of written or oral comments on the revised proposed plan for the amendment to the ROD. Upon timely request, the lead agency will extend the public comment period by a minimum of 30 additional days;
- Have provided the opportunity for a public meeting to be held during the public comment period at or near the facility at issue;
- Have kept a transcript of comments received at the public meeting held during the public comment period;
- Will include in the amended ROD a brief explanation of the amendment and the response to each of the significant comments, criticisms, and new relevant information submitted during the public comment period;
- Will publish a notice of the availability of the amended ROD in a major local newspaper of general circulation; and
- Will make the amended ROD and supporting information available to the public in the administrative record and information repository prior to the commencement of the remedial action affected by the amendment.

The Administrative Record File, including all referenced documents, for the site is available at:

Grand Island Public Library
211 North Washington Street
Grand Island, Nebraska 68802
(308) 385-5333
Hours of operation:
M-Th 9 a.m. – 9 p.m.
Fr-Sat 9 a.m. – 6 p.m.
Sun 1 p.m. – 5 p.m.

- ICF Kaiser Engineers. 1996. Remedial Investigation/Feasibility Study Report. Final Document. Cornhusker Army Ammunition Plant. Prepared for U.S. Army Environmental Center. November.
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- United States Army Environmental Center (USAEC). 1994a. Proposed Plan. Cornhusker Army Ammunition Plant Operable Unit One, Explosives Groundwater Plume. May.
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- United States Army Environmental Center (USAEC). 1996. Explanation of Significant Differences. Operable Unit One – Groundwater. Cornhusker Army Ammunition Plant.
- United States Environmental Protection Agency (USEPA). 1997. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17. December 1.
- United States Environmental Protection Agency (USEPA). 2000. Drinking Water Regulations and Health Advisories. EPA-822-B-00-001. Summer.
<http://www.epa.gov/ost/drinking/standards/summary.html>.
- URS Corporation (URS). 2000a. Technical Plan Addendum for March 2000 Sampling Event for the Long-Term Monitoring Program. Cornhusker Army Ammunition Plant. Prepared for USACE. February.
- URS Corporation (URS). 2000b. March 2000 Annual Sampling Event for the Long-Term Monitoring Program. Draft Report. Cornhusker Army Ammunition Plant. Prepared for USACE. July.
- URS Greiner Corporation (URS). 2001. Groundwater Flow and Contaminant Fate and Transport Modeling. Final Report. Cornhusker Army Ammunition Plant. Prepared for USACE. April.
- URS Greiner Woodward Clyde Federal Services (URSGWCFS). 1999. March 1999 Annual Sampling Event for the Long-Term Monitoring Program. Cornhusker Army Ammunition Plant. Prepared for USACE. October.

- Watkins-Johnson Environmental, Inc (WJE). 1994. Focused Feasibility Study for Groundwater – Operable Unit One. Cornhusker Army Ammunition Plant. Prepared for U.S. Army Environmental Center. March.
- Woodward-Clyde (W-C). 1997. 1996 Annual Long-Term Monitoring. Final Report. Cornhusker Army Ammunition Plant. Prepared for USAEC. July.
- Woodward-Clyde (W-C), 1998a. October 1997 Annual Sampling Event for the Long-Term Monitoring Program. Final Report. Cornhusker Army Ammunition Plant. Prepared for USACE. March
- Woodward-Clyde (W-C). 1998b. Draft Technical Plan for Long-Term Monitoring Program. Cornhusker Army Ammunition Plant. Prepared for USACE. April.
- Woodward-Clyde (W-C). 1998c. Technical Plan Addendum for June 1998 Groundwater Sampling Event for Long-Term Monitoring Program. Cornhusker Army Ammunition Plant. Prepared for USACE. June 5, 1998.
- Woodward-Clyde (W-C). 1999. June 1998 Annual Sampling Event for the Long-Term Monitoring Program. Final Report. Cornhusker Army Ammunition Plant. Prepared for USACE. February.

TABLE 1

**REMEDIAL ACTION OBJECTIVES
CORNHUSKER ARMY AMMUNITION PLANT
GRAND ISLAND, NEBRASKA**

Explosives Compound	Remedial Action Objective (parts per Billion)
TNT	2
HMX	400
RDX	2

TABLE 2

SUMMARY OF REMEDIES
CORNHUSKER ARMY AMMUNITION PLANT
GRAND ISLAND, NEBRASKA

	Original Selected Remedy	New Proposed Remedy
On-Post Groundwater	<u>Groundwater Extraction:</u>	<u>Groundwater Extraction:</u>
	EW-1 at 50 gpm	EW-1 at 0 gpm
	EW-2 at 100 gpm	EW-2 at 0 gpm
	EW-3 at 50 gpm	EW-3 at 0 gpm
	EW-4 at 50 gpm	EW-4 at 50 gpm
	EW-5 at 200 gpm	EW-5 at 200 gpm
	<u>EW-6 at 250 gpm</u>	EW-6 at 250 gpm
	Total at 700 gpm	<u>EW-7 at 250 gpm</u>
		Total at 750 gpm
	<u>Groundwater Treatment:</u>	<u>Groundwater Treatment:</u>
	– Granular Media Filtration (suspended solids pre-treatment)	– Granular Media Filtration (suspended solids pre-treatment)
	– Granular Activated Carbon (explosives treatment)	– Granular Activated Carbon (explosives treatment)
	– Wetland System (nitrates treatment)	– Wetland System (nitrates treatment)
	<u>Effluent Disposal:</u>	<u>Effluent Disposal:</u>
	– Discharge to Silver Creek	– Discharge to Silver Creek
	<u>Groundwater Monitoring</u>	<u>Groundwater Monitoring</u>
	<u>Institutional Controls:</u>	<u>Institutional Controls:</u>
	– Prohibit water supply well drilling in the impacted area	– Prohibit water supply well drilling in the impacted area
		– Deed restrict excessed property to prohibit water supply well drilling in the impacted areas and prohibit residential land use
		– Enforce the Hall County Reuse Plan that designates excessed CHAAP property as agricultural and industrial use only

TABLE 2

SUMMARY OF REMEDIES
CORNHUSKER ARMY AMMUNITION PLANT
GRAND ISLAND, NEBRASKA

	Original Selected Remedy	New Proposed Remedy
Off-Post Groundwater	<u>Groundwater Extraction:</u> Distal-1 at 150 gpm Distal-2 at 700 gpm <u>Distal-3 at 300 gpm</u> Total at 1150 gpm	
	<u>Groundwater Treatment:</u> – Granular Media Filtration (suspended solids pre-treatment) – Granular Activated Carbon (explosives treatment) – Wetland System (nitrates treatment)	Monitored Natural Attenuation
	<u>Effluent Disposal:</u> – Discharge to Silver Creek	
	<u>Groundwater Monitoring</u>	<u>Groundwater Monitoring</u>
	<u>Institutional Controls:</u> – Provide municipal water supply to all impacted residences – Public information and education program through Public Meetings and Press Releases	<u>Institutional Controls:</u> – Provide municipal water supply to all impacted residences – Public information and education program through Public Meetings and Press Releases – Establish a City “Overly Zone” Ordinance prohibiting drinking water supply well drilling in the impacted areas

Notes:

Groundwater monitoring for both remedies includes sampling on- and off-post monitoring wells for explosives concentrations and off-post wells for natural attenuation parameters. Annual sampling events and reporting are planned.

TABLE 3

CHEMICAL-SPECIFIC ARARs/TBCs

CORNHUSKER ARMY AMMUNITION PLANT – GRAND ISLAND, NEBRASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
<u>Federal</u>			
Health Advisory Levels (HALs)	Drinking Water Regulations and Health Advisories	Estimates of acceptable drinking levels for a chemical substance based on health effects information.	HALs are not included in a promulgated regulation. HALs are TBCs used as guidance to establish Remedial Action Objectives for chemicals without established MCLs.
Safe Drinking Water Act	42 USCA Sect. 300		
National Primary Drinking Water Regulations and National Revised Primary Drinking Water Regulations	40 CFR Part 141	Establishes maximum contaminant levels (MCLs), health-based standards for specific contaminants. MCLs are applicable for drinking water as supplied to the end users of public water supplies.	MCLs are relevant and appropriate for contamination of groundwater that is or may be used as drinking water. MCLs that have been published as final but are not yet in effect are TBCs. MCLs are relevant for deriving NPDES discharge levels.
National Primary Drinking Water Implementation Regulations	40 CFR Part 142	Establishes procedures for granting variances from MCL requirements. Specifies best technologies for treatment of various pollutants.	Requirements relevant and appropriate for determining cleanup goals for certain contaminants, if the MCL is not used or is available.
National Secondary Drinking Water Standards	40 CFR Part 143	Establishes secondary MCLs which are guidelines for public drinking water systems to protect the aesthetic quality of the water. Secondary MCLs are not Federally enforceable.	TBC if any of these constituents are addressed by a remedial action alternative, or if any treated and discharged groundwater is to be used as a source of drinking water. Relevant for deriving NPDES discharge levels.
Maximum Contaminant Level Goals (MCLGs)	40 CFR Parts 141, 142	Establishes non-enforceable health goals for drinking water quality at a level at which no adverse health effects may arise with an adequate margin of safety.	TBC for determination of groundwater cleanup levels and NPDES discharge levels. The MCL is the controlling ARAR.

TABLE 3

CHEMICAL-SPECIFIC ARARs/TBCs

CORNHUSKER ARMY AMMUNITION PLANT – GRAND ISLAND, NEBRASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Water Pollution Control Act, as amended	33 USCA Sect. 1251 et seq.		
Ambient Water Quality Criteria	40 CFR Part 131 Quality Criteria for Water	Requires states to establish ambient water quality criteria for surface water based on use classifications and the criteria stated under Section 304(a) of the Clean Water Act.	Ambient water quality criteria are relevant and appropriate because treated groundwater is discharged to surface water. State ambient water quality criteria are the applicable ARAR.
Guidelines Establishing Test Procedures for the Analysis of Pollutants	40 CFR Sect. 136.1-5 and Appendices A-C	Specific analytical procedures for NPDES applications and reports.	Applicable because treated groundwater is discharged to a surface water.
Pretreatment Standards	40 CFR 403	Applies to discharges of pollutants to publicly-owned treatment works (POTWs). Requires that such pollutants not interfere with operation of the POTW, or pass through the POTW at concentrations which cause a violation of the POTW NPDES permit.	Applicable only if investigation-derived wastewater, treated groundwater, or other wastewater is discharged to a municipal wastewater treatment system. Categorical standards may be relevant and appropriate.
Solid Waste Disposal Act (SWDA), as amended	42 USCA Sect. 6901-6992K		
Identification and Listing of Hazardous Waste	40 CFR Part 261	Defines characteristics of hazardous wastes and provides lists of hazardous wastes. Identifies solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 124, 262-265, 268, 270, and 271.	Applicable to wastes generated by remedial activities, including investigation-derived wastes, excavated soil, or solid wastes generated by treatment of soil, groundwater, or hazardous wastes.
Releases from Solid Waste Management Units	40 CFR Part 264.94	Subpart F (264.94) gives concentration limits in groundwater for hazardous constituents from a regulated unit.	Applicable if listed hazardous constituents are found in groundwater.

TABLE 3
CHEMICAL-SPECIFIC ARARs/TBCs
CORNHUSKER ARMY AMMUNITION PLANT – GRAND ISLAND, NEBRASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
<u>State</u>			
Nebraska Environmental Protection Act	Neb. Rev. Stat., Chapter 81	State's policy on environmental control.	
Nebraska Surface Water Quality Standards	Neb. Adm. Rules & Regs., Title 117	Establishes water quality standards and criteria for the surface waters of the state.	Applicable because treated groundwater is discharged to surface waters.
Ground Water Quality Standards and Use Classification	Neb. Adm. Rules & Regs., Title 118	Establishes groundwater quality standards and use classifications for groundwater sources. Used to determine priorities for groundwater remedial actions.	State MCLs are ARARs for contaminated groundwater if the state MCL is more stringent than federal requirements. The antidegradation clause (Chapter 3) provides that if the existing quality of any groundwater is better than the MCLs, that quality will be maintained and protected.
Rules and Regulations Pertaining to the Issuance of Permits under the NPDES, Effluent Guidelines and Standards	Neb. Adm. Rules & Regs., Titles 119 and 121	Establishes effluent limitations and procedures for determining effluent limitations.	Applicable if state standards are more stringent than federal requirements.
Regulations Governing Public Water Supply Systems	Neb. Adm. Rules & Regs., Title 179	Establishes MCLs for public water supply systems.	Relevant and appropriate for contaminated groundwater if the state MCL is more stringent than federal requirements.
	Neb. Adm. Rules & Regs., Title 129, Chapter 32	Prohibits visible emissions of fugitive particulate matter beyond the premises where it originates.	Applicable if remedial activities, such as soil excavation or grading, generate fugitive dust.

¹ Nebraska's Air Quality Regulations were last amended May 29, 1995.

TABLE 4

LOCATION-SPECIFIC ARARs

CORNHUSKER ARMY AMMUNITION PLANT – GRAND ISLAND, NEBRASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
<u>Federal</u>			
Floodplain Management	Executive Order 11988 40 CFR Part 6, Appendix A and 40 CFR Part 6.302	Limits activities in a floodplain, which is defined as “the lowland and relatively flat areas adjoining inland and coastal waters including at a minimum that area subject to a 1 percent or greater chance of flooding in any given year” (the 100-year floodplain)	Applicable if remedial actions occur in the 100-year floodplain.
100-Year Floodplain Management	40 CFR 264.18(b)	RCRA treatment, storage, or disposal facility must be designed, constructed, operated, and maintained to avoid washout within 100-year floodplain.	Applicable if remedial actions occur in the 100-year floodplain.
Protection of Wetlands	Executive Order 11990 40 CFR Part 6, Appendix A	Addresses possible impacts of construction of facilities or management of property in wetlands; must avoid adverse effects, minimize potential harm, and preserve and enhance wetlands, to the extent possible.	Applicable if wetlands occur at proposed remedial action locations.
Water Pollution Control Act, as amended	33 USCA Sect. 1251 et seq. (CWA Section 404) 40 CFR Part 230 33 CFR Parts 320-330	Prohibits discharge of dredged or fill material into wetlands (as defined in U.S. Army Corps of Engineers regulations) without permit.	Applicable if dredged or fill material will be placed into a wetland during remedial actions.
Solid Waste Disposal Act (SWDA), as amended	42 USCA Sect. 6901-6992K		
Floodplains	40 CFR Part 264.18(b)	RCRA treatment, storage, or disposal facility must be designed, constructed, operated, and maintained to avoid washout within 100-year floodplain.	Applicable if remedial actions occur in the 100-year floodplain.

TABLE 4

LOCATION-SPECIFIC ARARs
CORNHUSKER ARMY AMMUNITION PLANT – GRAND ISLAND, NEBRASKA

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Farmland Protection Policy Act	7 USC 420 et seq.	Establishes requirement for federal agencies for acquiring, managing and disposing of lands and facilities; or provide criteria that identify and take into account the adverse effects of actions on the preservation of farmland.	Relevant and appropriate if treatment facility location and project related activities affect farmland.
Fish and Wildlife Coordination Act	16 USCA Sect. 661 et seq. 33 CFR Parts 320-330 40 CFR Part 6.302	Establishes requirements for action taken to prevent, mitigate, or compensate for project-related damages or losses to fish and wildlife resources.	Applicable to effluent structures in or near a stream or river.
Archaeological and Historic Preservation Act of 1974	16 USCA Sect. 469; 36 CFR Part 65	Must recover and preserve artifacts in area where alteration of terrain threatens significant scientific, prehistorical, or archaeological data.	Applicable if artifacts are found during remedial activities.
National Historic Preservation Act of 1966, as amended	16 USCA Sect. 470 et seq. 36 CFR Part 800 40 CFR Sect. 6.301	Must preserve property in or eligible for National Register of Historic Places; actions should minimize harm to National Historic Landmarks.	Applicable if eligible property are potentially impacted during remedial activities.
Native American Graves Protection and Repatriation Act	PL 101-601	Requires that if Native American remains or cultural items are found on federal lands, the appropriate tribe must be notified, and all activity in the area of discovery must cease for at least 30 days.	Applicable if Native American remains or cultural items are found during remedial activities.
Antiquities Act of 1906	16 USCA 431-433 43 CFR Part 3	Provides for protection of historic and prehistoric ruins and objects on Federal lands.	Applicable if historical ruins or objects are found during remedial activities.
<u>State</u>			
Nebraska Human Burial Sites Act	Neb. Rev. Stat., Article 12, Sections 12-1201 to 1212.	Provides protection for unmarked human burial sites on private and public lands.	Applicable if human burial sites are discovered during remedial activities.

TABLE 4

**LOCATION-SPECIFIC ARARs
CORNHUSKER ARMY AMMUNITION PLANT – GRAND ISLAND, NEBRASKA**

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Floodplains	Neb. Rev. Stat., Chapter 31, Article 10, Neb. Adm. Rules & Regs., Title 455, Chapters 1 through 7.	Regulates, and requires permits for, certain activities proposed to take place in a floodplain.	Applicable if remedial activities occur in the 100- year floodplain.

TABLE 5

ACTION-SPECIFIC ARARs/TBCs

CORNHUSKER ARMY AMMUNITION PLANT

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Safe Drinking Water Act	42 USCA Sect. 300(f) et seq.		
Standards for Owners and Operators of Public Water Supply System	40 CFR Part 141	Establishes primary drinking water regulations, including treatment (water quality) requirements for public water supply systems.	Remedial action will not involve designing a public water supply treatment system; however, primary levels (MCLs) may be applicable to treatment of groundwater.
Clean Water Act	33 USCA Sect. 1251-1376		
National Pollutant Discharge Elimination System	40 CFR Parts 122, 125	Requires permits for the discharge of pollutants from any point source into waters of the United States.	Substantive requirements applicable for remedial actions that involve point source discharges to surface waters. May be applicable to treatment system discharges.
	40 CFR Sect. 122.26(b)(14)(x)	Requires that storm water runoff be monitored and controlled on construction sites greater than five acres.	Applicable if the remediation site is greater than five acres, relevant and appropriate for smaller sites.
Wetland Protection	CWA 404 40 CFR 230.3 (1) 33 CFR 328 (b)	Established requirements to avoid degradation of wetland due to construction activities	Applicable to construction activities near wetlands which may be present along pipeline or well locations.
Hazardous Materials Transportation Act	40 USCA Sect. 1801-1813		
Hazardous Materials Transportation Regulations	49 CFR Parts 107, 171-177	Regulates transportation of hazardous materials.	Applicable for remedial actions that involve off-site transportation of hazardous materials. (e.g., spent carbon or sludge disposal)

TABLE 5

**ACTION-SPECIFIC ARARs/TBCs
CORNHUSKER ARMY AMMUNITION PLANT**

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Occupational Safety and Health Act of 1970	PL 91-596 29 USCA Sect. 651-678		
Occupational Safety and Health Standards	29 CFR Part 1910	Establishes safety and health requirements for personnel working with hazardous materials and hazardous waste.	Applicable to on-site remedial activities and long term operation and maintenance of treatment system.
Safety and Health Regulations for Construction	20 CFR Part 1926	Establishes protection standards (e.g., hazard communication, excavation and trenching requirements) for workers involved in hazardous waste operations.	Applicable to on-site remedial activities.
<u>State</u>			
Nebraska Environmental Protection Act	Neb. Rev. Stat., Chapter 81 Article 15		
Nebraska Surface Water Quality Standards	Neb. Adm. Rules & Regs., Title 117	Establishes water quality standards and criteria for the surface waters of the state.	Applicable because contaminated water is treated and discharged into surface waters.
Ground Water Quality Standards and Use Classification	Neb. Adm. Rules & Regs., Title 118	Provides groundwater remedial actions protocol for point source groundwater pollution; defines Remedial Action Classes (RACs) with basic requirements for remedial action.	Relevant and appropriate for remedial actions addressing groundwater pollution at this site.
Rules and Regulations Pertaining to the Issuance of Permits under the NPDES	Nebr. Adm. Rules & Regs., Title 119	Requires permit for discharging pollutants from a point source into the waters of the State.	Substantive requirements are applicable to point source discharges to surface water.
Effluent Guidelines and Standards	Neb. Adm. Rules & Regs., Title 121	Establishes point source effluent standards and secondary treatment standards for industries.	Applicable to point source discharges to surface water.

TABLE 5

**ACTION-SPECIFIC ARARs/TBCs
CORNHUSKER ARMY AMMUNITION PLANT**

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Design, Operation, and Maintenance of Wastewater Treatment Facilities	Neb. Adm. Rules & Regs., Title 123	Establishes procedures for the design, operation, and maintenance of wastewater treatment works, including the submittal of plans, receipt of construction permits, and construction and testing requirements.	Applicable for on-site treatment of extracted groundwater.
Rules and Regulations Pertaining to the Management of Wastes	Neb. Adm. Rules & Regs., Title 126	Requires permits for licenses for various waste management activities and establishes policy for releases of oil or hazardous substances and remediation of such releases.	Substantive requirements for spills/releases and remediation of spills/releases are given in Title 118 and Title 128.
Rules and Regulations Governing Hazardous Waste Management in Nebraska	Neb. Adm. Rules & Regs., Title 128	Establishes procedures for notification of hazardous waste activity, identification and listing of hazardous wastes, generators, and operators of treatment, storage, and disposal facilities.	Substantive requirements that are the same or more stringent than 40 CFR 261, 262, 263, 264, 268, 270 are applicable.
Air Pollution Control Rules and Regulations ¹	Neb. Adm. Rules & Regs., Title 129, Chapter 2	Defines “major source” of hazardous air pollutants and major stationary sources of other pollutants, including fugitive dust and other particulate emissions.	Applicable to remedial activities generating fugitive dust, and potentially applicable to remedial alternatives involving volatilization or incineration.
	Neb. Adm. Rules & Regs., Title 129, Chapter 20	Prohibits visible dust beyond the limits of the property line where handling, transportation, or construction is taking place.	Applicable to remedial activities generating fugitive dust.
	Neb. Adm. Rules & Regs., Title 129, Chapter 39	Limits visible emissions from diesel-powered vehicles on public streets or highways.	Applicable only when diesel-powered vehicles used during remedial activities are on public streets or highways.

TABLE 5**ACTION-SPECIFIC ARARs/TBCs
CORNHUSKER ARMY AMMUNITION PLANT**

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Regulations Governing Licensure of Water Well and Pump Installation Contractors and Certification of Water Well Drilling, Pump Installation, and Water Well Monitoring Supervisors	Neb. Adm. Rules & Regs., Title 178, Chapter 10	Contains rules governing the qualifications of contractors installing water wells.	Applicable for installation of monitoring wells, extraction of recovery wells, and the installation of pumps.
Regulations Governing Water Well Construction, Pump Installation, and Water Well Abandonment Standards	Neb. Adm. Rules & Regs., Title 178, Chapter 12	Contains rules governing water well construction and abandonment and pump installation.	Applicable for installation of monitoring wells, extraction or recovery wells, and the installation of pumps.

¹ Nebraska's air quality regs were last amended May 29, 1995.

TABLE 6

**DETAILED ANALYSIS OF REMEDIES
CORNHUSKER ARMY AMMUNITION PLANT
GRAND ISLAND, NEBRASKA**

Evaluation Criterion	Original Selected Remedy	New Proposed Remedy
Overall Protection of Human Health and the Environment		
Human Health Protection	Protection of human health in the short-term through installation of a public water supply system. Possible human health risk not mitigated through institutional actions includes installation of new water supply wells, or continued use of impacted supply wells.	Protection of human health in the short-term through installation of a public water supply system. Increased protection of human health through additional institutional controls (e.g., City Ordinance).
Environmental Protection	Protects groundwater downgradient of source areas from further contamination. Also protects further aquifer degradation at the distal end of the plume.	Protects groundwater downgradient of source areas and CHAAP property boundary from further contamination. No engineered control of distal plume migration, but MNA would degradation track and provide early exposure and migration warnings.
Compliance with ARARs		
Compliance with ARARs	Meets ARARs.	Meets ARARs.
Appropriateness of Waivers	None required.	None required.
Long-Term Effectiveness and Permanence		
Magnitude of Residual Risk	Residual risks include potential continued use of the impacted aquifer for water supply.	Residual risks mitigated through increased institutional actions.
Adequacy and Reliability of Controls	Groundwater extraction and treatment are proven technologies. Institutional controls do not eliminate residual risk to human exposure.	Groundwater extraction and treatment are proven technologies. Institutional actions are expected to be reliable at eliminating residual risks to human exposure. MNA demonstrated to be adequate and reliable.
Need for 5-Year Review	Review would be required to ensure adequate protection of human health and the environment is maintained.	Review would be required to ensure adequate protection of human health and the environment is maintained.
Reduction of Toxicity, Mobility, and Volume		
Treatment Processes Used	Groundwater extraction and treatment using conventional groundwater extraction wells, pre-treatment using granular media filtration, and treatment in granular activated carbon vessels.	Groundwater extraction and treatment using conventional groundwater extraction wells, pre-treatment using granular media filtration, and treatment in granular activated carbon vessels. MNA uses natural process of biodegradation, abiotic oxidation, hydrolysis, sorption, and dispersion.
Amount destroyed or treated	Ultimately the entire dissolved-phase groundwater plume would be treated.	Ultimately the entire dissolved-phase groundwater plume would be treated.
Reduction of TMV	Toxicity reduced by transfer to GAC. Mobility enhanced upgradient of groundwater extraction wells, but eliminated downgradient of the distal wells. Volume of contaminated groundwater reduced by extraction.	Toxicity on-post reduced by transfer to GAC. Toxicity off-post reduced by natural attenuation mechanisms. Mobility enhanced upgradient of groundwater extraction wells, but eliminated downgradient of the facility boundary. Volume of contaminated groundwater reduced by extraction on-post and MNA off-post.
Irreversible treatment	Adsorption to GAC reversible.	Adsorption to GAC reversible. Biodegradation is irreversible.
Type and quantity of residuals remaining after treatment	Residuals remaining from treatment process include spent GAC and sludge.	Residuals remaining from treatment process include spent GAC and sludge.

TABLE 6

**DETAILED ANALYSIS OF REMEDIES
CORNHUSKER ARMY AMMUNITION PLANT
GRAND ISLAND, NEBRASKA**

Evaluation Criterion	Original Selected Remedy	New Proposed Remedy
Short-Term Effectiveness		
Time Required to Achieve Remedial Action Objectives ¹	Estimated between 40 and 50 years on-post and between 10 to 20 years off-post.	Estimated between 40 and 50 years on-post and between 10 to 20 years off-post.
Protection of Community During Remedial Action	On-post work should not effect community. Off-post work can be done safely with adequate traffic signage and construction control.	On-post work should not effect community. Off-post work can be done safely with adequate traffic signage and construction control.
Protection of Workers During Remedial Action	Workers can be protected through proper health and safety training and PPE.	Workers can be protected through proper health and safety training and PPE.
Environmental Impacts During Remedial Action	Potential need for considerable dewatering during construction of conveyance piping from extraction wells to the treatment facility. This water would require temporary storage, treatment, and disposal. Dewatering concerns are heightened off-post due to public health and safety concerns.	Potential need for considerable dewatering during construction of conveyance piping from extraction wells to the treatment facility. This water would require temporary storage, treatment, and disposal.
Implementability		
Ability to Construct and Operate	On-post portion constructed and operable. Off-post distal wells and conveyance piping were tabled due to extreme administrative implementability problems. Real estate transfers, permanent easements, and use of public right-of-ways caused off-post construction to be delayed. Long-term monitoring requires continued support and permission from private land owners.	On-post portion constructed and operable. No off-post constuction required. Long-term monitoring requires continued support and permission from private land owners.
Ease of doing more remedial action, if needed	Simple to expand or augment on-post systems. Off-post expansion limited by real estate constraints.	Simple to expand or augment on-post systems. Off-post expansion limited by real estate constraints.
Ability to monitor effectiveness	LTM will prove effectiveness of source area control/removal and containment/removal of the off-post plume.	LTM will prove effectiveness of source area control/removal and degradation via natural attenuation off-post.
Ability to obtain approvals and coordination with other agencies	Difficult to gain approval from local agencies and property owners. Difficulty related to real estate access.	Approval and coordination with other agencies not expected to be a concern.
Availability of services and equipment	Commercially available.	Commercially available.
Technical Feasibility	Technologies are available and equipment is easily obtained.	Technologies are available and equipment is easily obtained.

TABLE 6

**DETAILED ANALYSIS OF REMEDIES
CORNHUSKER ARMY AMMUNITION PLANT
GRAND ISLAND, NEBRASKA**

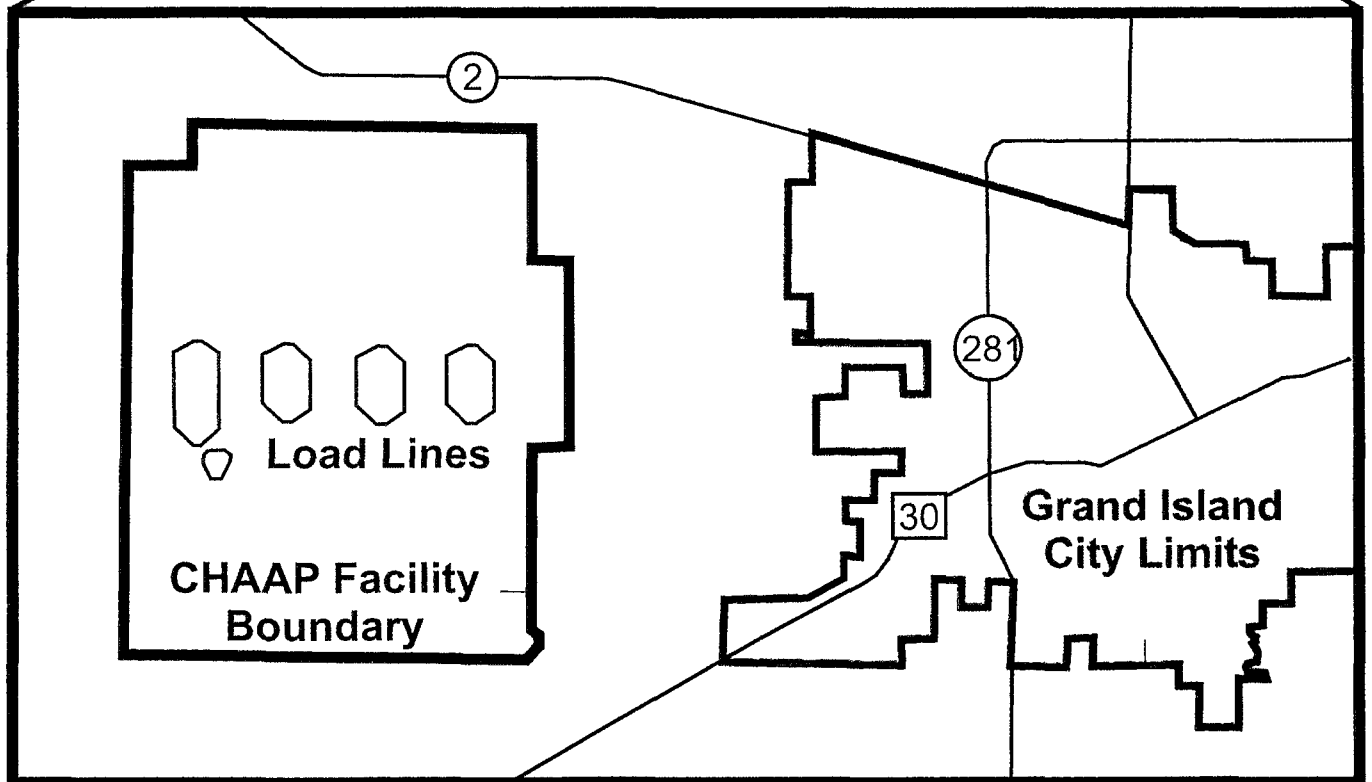
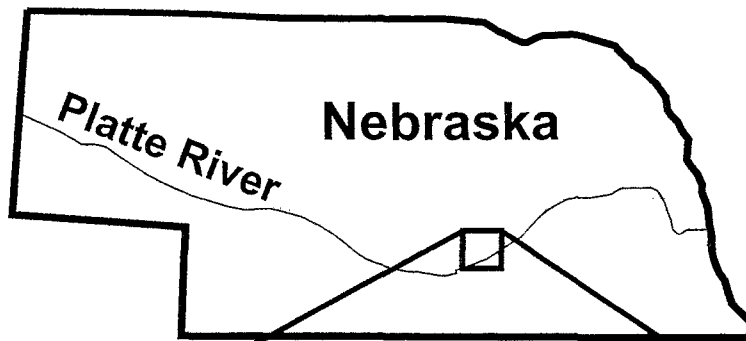
Evaluation Criterion	Original Selected Remedy	New Proposed Remedy
State/Support Agency Acceptance	Selected Remedy previously approved by the USEPA and NDEQ in the ROD (USAEC 1994)	The USEPA and NDEQ support the new Proposed Remedy.
Community Acceptance	The community formally expressed concerns about the Original Selected Remedy which was subsequently selectively implemented. Public comments included concerns about: effluent discharge to infiltration basins and Silver Creek creating flooding or a rise in the regional groundwater table, distal well pumping increasing levels of contamination within Grand Island City Limits due to increased groundwater flow velocities, and real estate concerns regarding the construction of the distal well system conveyance piping.	Community acceptance of the New Proposed Remedy will be evaluation and incorporated into the final ROD amendment.
Estimated Relative Costs		
Capital Costs	\$13,000,000	\$9,700,000
Annual OM&M	\$1,200,000	\$800,000
Present Worth	\$37,000,000	\$26,000,000

Notes:

MNA - Monitored Natural Attenuation.

LTM - Long-term Monitoring

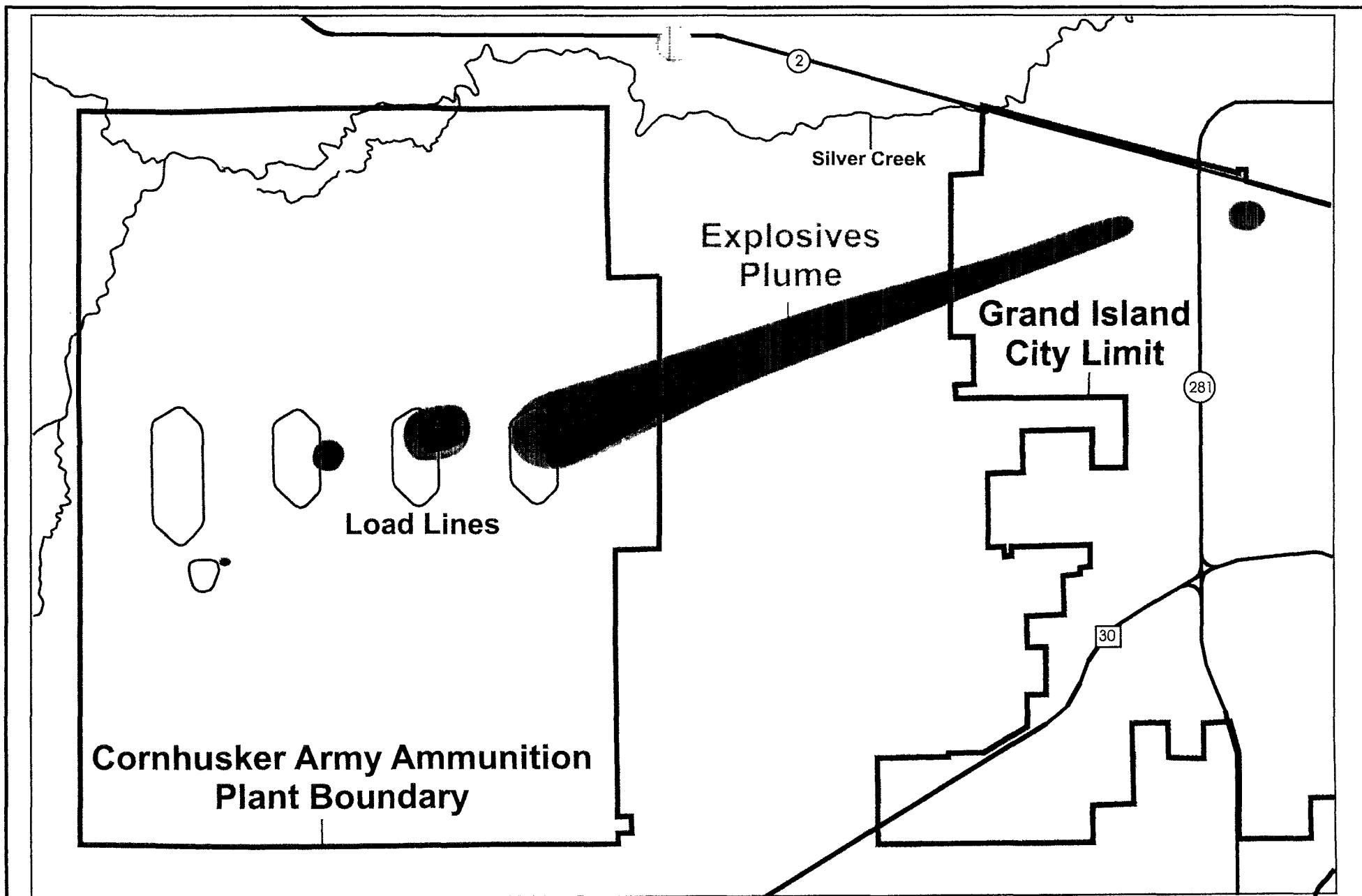
¹ - Estimated remedial time periods from Groundwater Flow and Contaminant Fate and Transport Modeling Report (URS 2000)² - Present worth calculated at seven percent discount rate for twenty years of operation and maintenance.





URS

Facility Location Map

DRN BY: JBH	DATE: 01/26/01	PROJECT NUMBER	FIG. NO.
CHK'D BY:	REVISION: 0	49-F0000009.00	1



LEGEND:

-  Interpreted horizontal extent of total explosives > 2 µg/L
-  Interpreted horizontal extent of total explosives > 200 µg/L

6,000 0 6,000
Scale: 1":6,000'



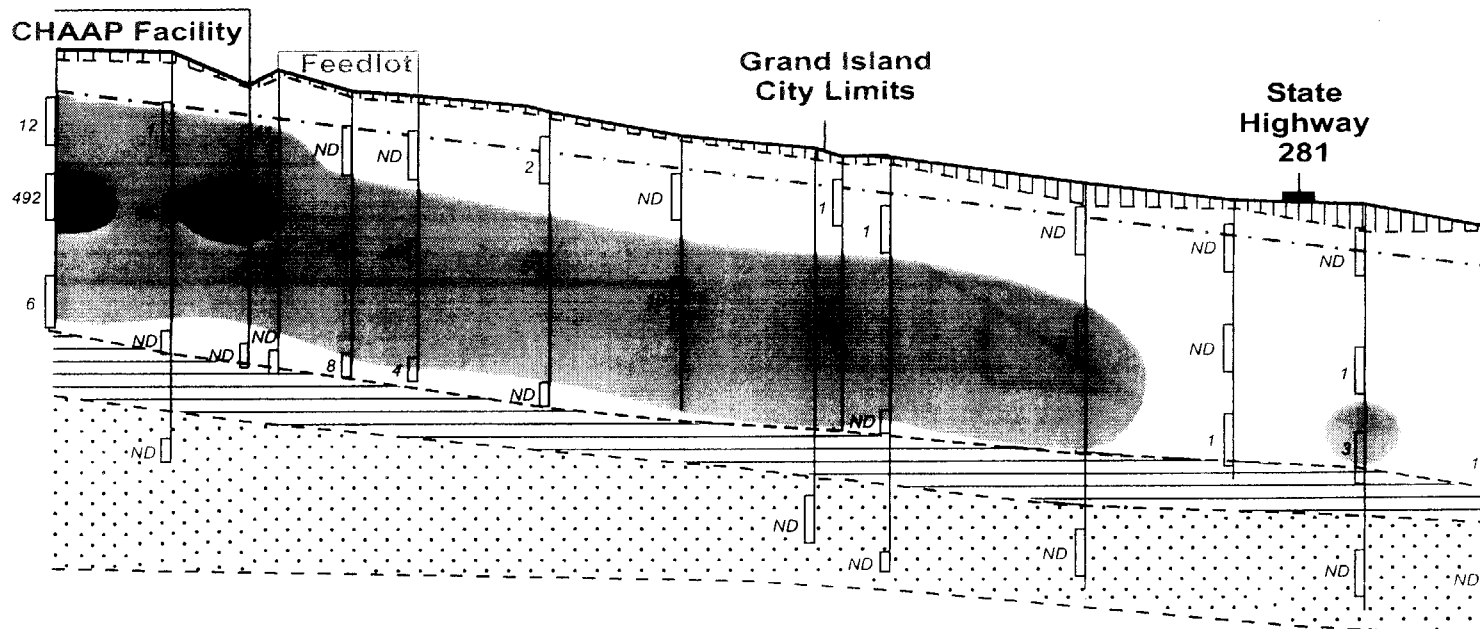
URS

Explosives Plume,
CHAAP, and Vicinity

DRN BY: JBH	DATE: 01/26/01	PROJECT NUMBER	FIG. NO.
CHK'D BY:	REVISION: 0	49-F0000009.00	2

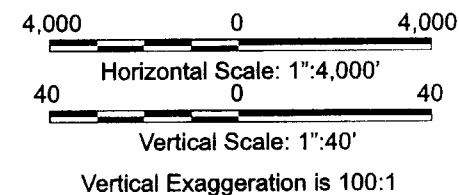
Southwest

Northeast



LEGEND:

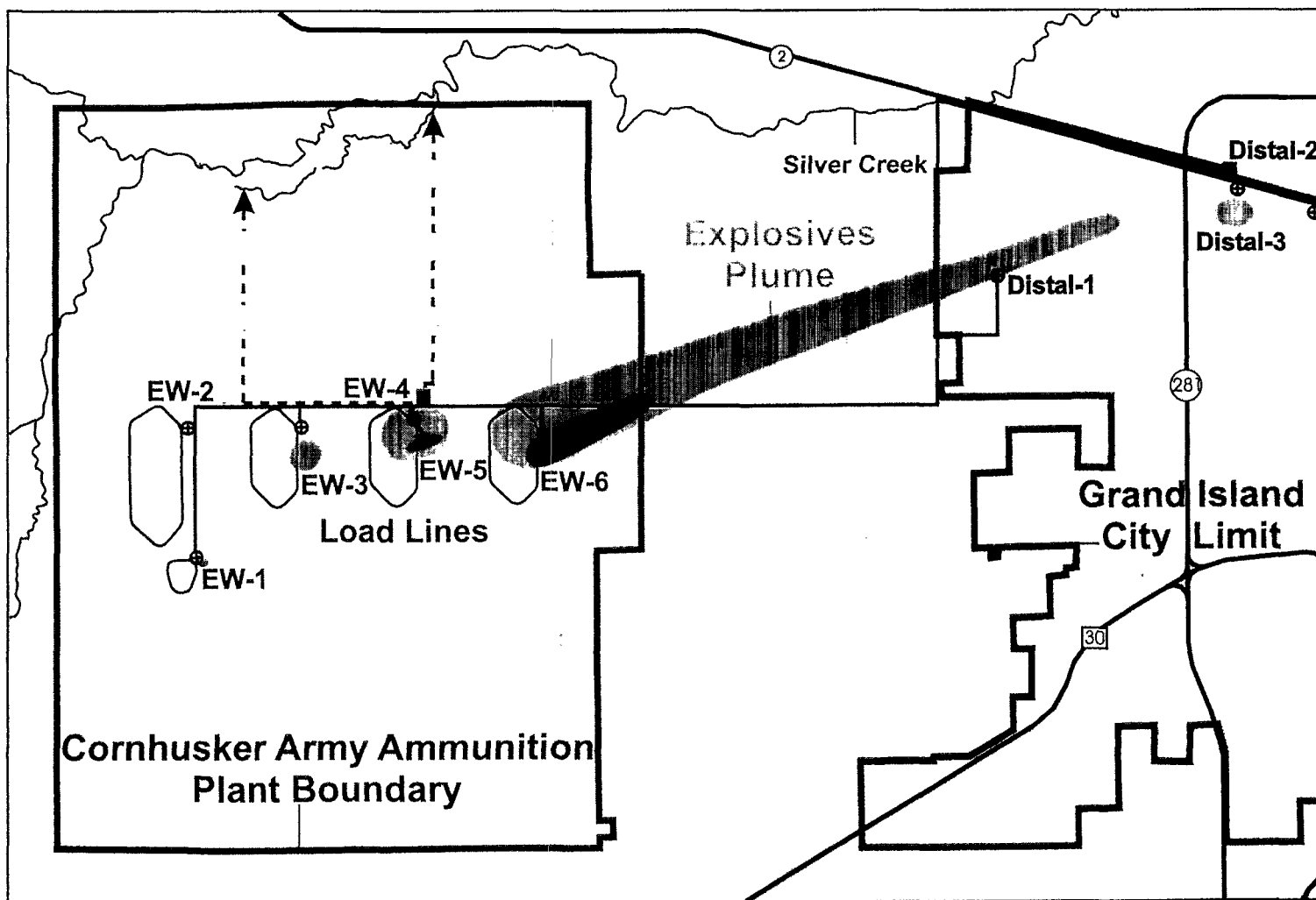
- Monitoring Well Location with March 2000 Total Explosives Concentrations in µg/L (ND = Non-detect)
- Water Table - March 2000
- Interpreted Vertical and Horizontal Extent of Total Explosives > 2 µg/L
- Interpreted Vertical and Horizontal Extent of Total Explosives > 200 µg/L
- Topsoil - Clay and Silt
- Grand Island Formation (Alluvial Sand Aquifer)
- Fullerton Formation (Blue Clay Aquitard)
- Holdredge Formation (Gravel Aquifer)



URS

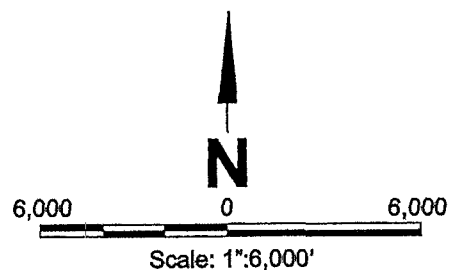
Cross-Sectional View of
The Off-Post Explosives Plume

DRN BY: JBH	DATE: 01/26/01	PROJECT NUMBER	FIG NO
CHK'D BY:	REVISION: 0	49-F0000009.00	3

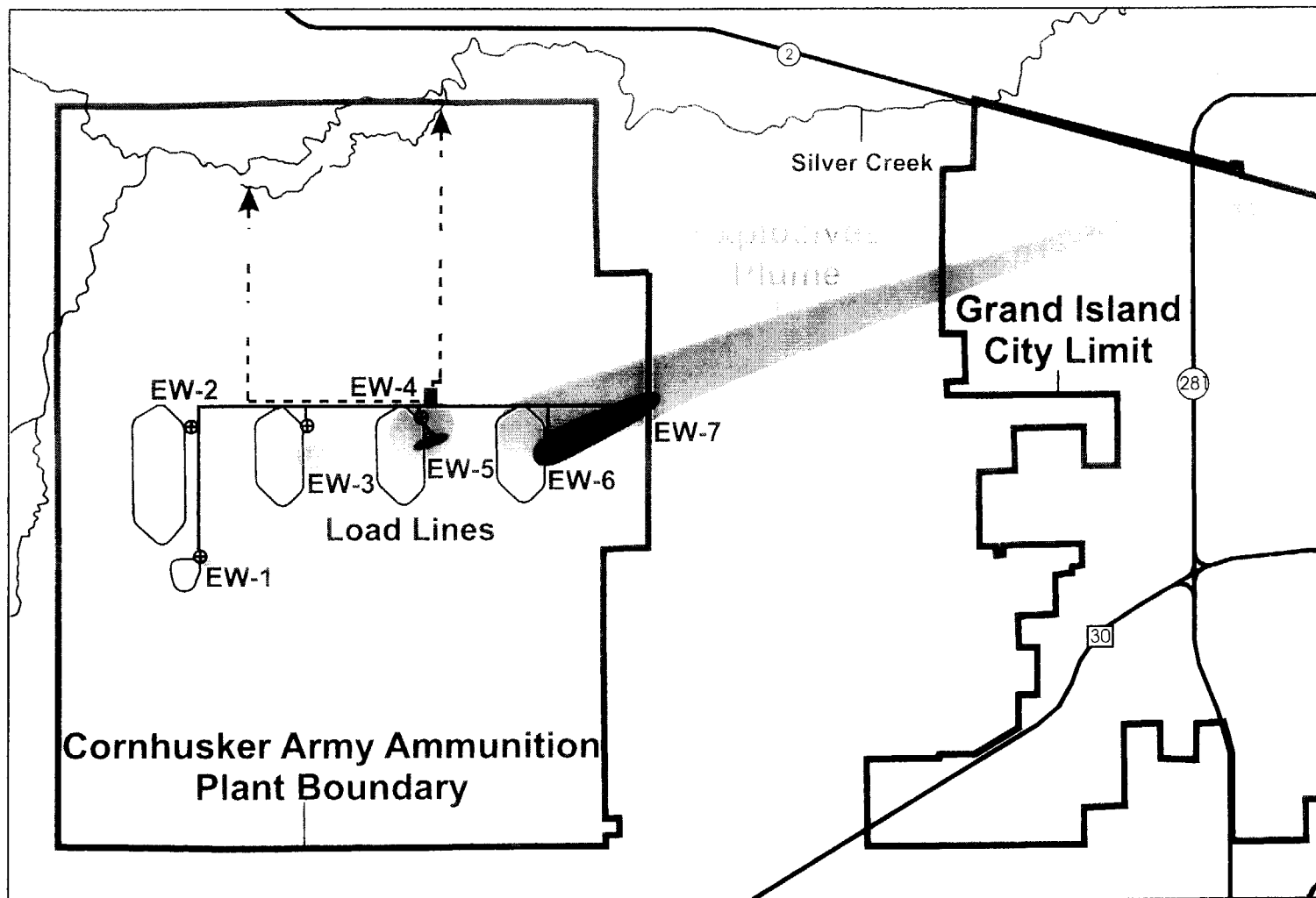


LEGEND:







- Interpreted horizontal extent of total explosives > 2 µg/L
- Interpreted horizontal extent of total explosives > 200 µg/L
- Groundwater Extraction Well
- Surface Discharge and Infiltration Basin
- Groundwater Piping
- Groundwater Treatment Facility

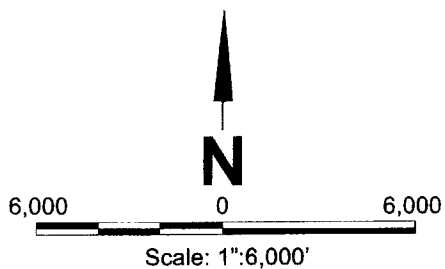


URS			
Original Selected Remedy			
DRN BY: JBH	DATE: 01/26/01	PROJECT NUMBER	FIG. NO.
CHK'D BY:	REVISION: 0	49-F0000009.00	4



LEGEND:

-  Interpreted horizontal extent of total explosives > 2 µg/L
-  Interpreted horizontal extent of total explosives > 200 µg/L
-  Groundwater Extraction Well
-  Surface Discharge and Infiltration Basin
-  Groundwater Piping
-  Groundwater Treatment Facility



URS			
New Proposed Remedy			
DRN BY: JBH	DATE: 01/26/01	PROJECT NUMBER	FIG NO
CHK'D BY:	REVISION: 0	49-F0000009.00	5

Administrative Record File – A compilation of documents that record the US Army’s decision-making process regarding the selection of a response action to be taken at a site.

Applicable or Relevant and Appropriate Requirements (ARARs) – The Federal and State environmental laws that a selected remedy will meet. These requirements may vary among sites and alternatives.

Biodegradation – The use of microorganisms to transform or alter, through metabolic or enzymatic action, hazardous organic contaminants into nonhazardous substances.

Capital Costs – Up-front costs associated with remediation system construction and start-up, administration, legal, engineering, and design.

Carcinogens – Potential cancer-causing chemicals. RDX and TNT are considered “possible” carcinogens, meaning there is data indicating carcinogenicity in animals but no data for humans.

Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) – The federal law that addresses problems resulting from releases of hazardous substances to the environment, primarily at inactive sites.

HMX (Cyclotetramethylenetetranitramine) – Common military explosive; not classified as a human carcinogen, but at high concentrations may cause other adverse health effects.

Distal End – The far end of the plume of affected groundwater in the off-post area.

Effluent – Process water leaving a treatment unit.

Groundwater Extraction – The process in which groundwater is pumped from an aquifer to the ground’s surface for treatment.

Feasibility Study (FS) – This CERCLA document develops and evaluates options for remedial action. The FS emphasizes data analysis and is generally performed concurrently in an interactive fashion with the Remedial Investigation (RI), using data gathered during the RI.

Granular Activated Carbon (GAC) – A water treatment method which uses fine-grained carbon to adsorb organic chemicals such as explosives from the water.

Hazard Quotient (HQ) – A numerical ratio used in risk assessments to describe the potential for non-carcinogenic adverse health effects to occur for a specific chemical and exposure pathway. If the HQ is greater than 1.0, then a hazard may exist and remedial action is usually warranted.

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) – These CERCLA regulations provide the federal government the authority to respond to the problems of abandoned or uncontrolled hazardous waste disposal sites as well as to certain incidents involving hazardous waste (e.g., spills).

National Priorities List (NPL) – USEPA’s list of uncontrolled or abandoned waste sites which present the greatest potential threat to human health or the environment.

Natural Attenuation – Natural processes such as biodegradation and other chemical reactions that reduce contaminant concentrations to acceptable levels.

Operable Unit – A portion of a site separately considered for remedial or corrective action. For example, Operable Unit One at CHAAP addresses the explosives groundwater plume.

Operations and Maintenance (O & M) – Measures required to operate and maintain remedial systems to ensure the effectiveness of the response action.

Preferred Remedial Alternative – The remedial alternative selected by the US Army, USEPA and NDEQ based on a comparison of various remedial alternatives using specific evaluation criteria.

Present Value – A value representing the entire lifetime cost of an alternative converted into an equivalent present cost using an assumed discount rate.

Revised Proposed Plan – CERCLA document that summarizes evidence to support the selection of a revised preferred alternative at a CERCLA site. The document is intended for public distribution to solicit comments on the proposed action(s).

Record of Decision (ROD) – The document that presents the final remedy selected by the concerned agencies for cleanup.

Remedial Investigation (RI) – A process under CERCLA to determine the nature and extent of the problem presented by a release. The RI includes sampling, monitoring, and gathering of sufficient information to determine the necessity for remedial action.

Resource Conservation and Recovery Act (RCRA) – The Federal act that established a regulatory system to track hazardous wastes from the time they are generated to final disposal.

Royal Demolition Explosive (RDX) - Hexahydro-1,3,5-trinitro-1,3,5-triazine – A common military munitions explosive; considered to be a possible human carcinogen.

Superfund Amendments and Reauthorization Act (SARA) – 1986 revision to CERCLA added provisions and clarified much of what was unclear in the original act.

Target Risk Range – A range of probabilities of carcinogenic risks to human health of 1×10^{-4} to 1×10^{-6} that is considered to be the risk range for health protection at Superfund sites. If calculated risks fall within the risk range, risk managers must determine whether remedial action is warranted to reduce the risk. If the risks are smaller than 1×10^{-6} (less than 1 in 1 million), no remedial action is required. If the risks are greater than 1×10^{-4} (1 in 10 thousand), remedial action is generally required.

Total Incremental Cost – The entire lifetime cost of an alternative assuming payments in the future are based on current costs.

2, 4, 6 – Trinitrotoluene (TNT) – Common military explosive; considered to be a possible human carcinogen and at higher concentrations may cause adverse health effects.

USEPA Health Advisory Levels – Contaminant concentration levels set by USEPA to be protective of human health.

The primary objective of the LTM program is to monitor and identify explosives plume migration trends in the off-post monitoring well locations. Additional objectives for the LTM included identifying natural attenuation trends for the off-post explosives plume. Five LTM and natural attenuation demonstration sampling events have been completed since 1996. The data from these events supports the use of monitored natural attenuation of the off-post explosives plume.

This appendix includes selected text and figures from the LTM events and Monitored Natural Attenuation Demonstration as published in the March 2000 Annual Sampling Event for the Long-Term Monitoring Program Draft Report (URS 2000). The entire report can be found in the administrative record at the Grand Island Public Library. All section numbers, text, tables, and figures remain unchanged from the original report.

The following sections are reproduced from the March 2000 Annual Sampling Event for the Long-Term Monitoring Program Draft Report (URS 2000b).

1.5 SCOPE OF WORK

The March 2000 annual sampling event was the fifth in a series of planned LTM sampling events. During the March 2000 sampling event, URS collected groundwater samples from 82 off-post wells, 42 on-post wells, and 14 on-post piezometers. The samples were analyzed for nitroaromatics and nitroamines using USEPA Method 8330. Groundwater samples were also analyzed for natural attenuation parameters, including alkalinity, ammonia, nitrate/nitrite, sulfate, total Kjeldahl nitrogen, dissolved organic carbon, and methane. All analyses were completed by EMAX Laboratories, Inc., Torrance, California. Water level readings and water quality parameters were also measured during well purging.

URS resampled 14 wells for explosives reanalysis on June 14 and 15, 2000. The original samples were analyzed outside of holding times for 10 of the 14 wells and were rejected. The four remaining wells were resampled to check the accuracy and precision of the original sample results. The use of the resampled well data is discussed in Section 4.0.

Prior to the March 2000 sampling event, 6 new monitoring wells were installed in December 1999.

1.6 OBJECTIVE

The primary objective of the LTM program is to monitor and identify explosives plume migration trends in the off-post monitoring well locations. Additional objectives for the March 2000 annual sampling event included measuring current explosives concentrations at selected on-post monitoring well locations and identifying natural attenuation trends for the off-post explosives plume.

SECTION FIVE**Nature and Extent of Contamination**

This section provides a description of the nature and extent of explosives detected in groundwater during the March 2000 sampling event at CHAAP. RDX, HMX, and TNT were selected for this discussion because of their frequency of occurrence, magnitude of detected concentrations, and potential adverse health effects.

Health advisory concentration levels for explosives were established for CHAAP in the ROD. This nature and extent discussion generally focuses on contaminant concentrations above the health advisory levels. These levels are:

- 2 µg/L for RDX and TNT
- 400 µg/L for HMX

5.1 HORIZONTAL EXTENT OF GROUNDWATER PLUME

Horizontal extent of total explosives, RDX, and TNT detected during the March 2000 sampling event are shown on **Figures 5-1a, 5-1b, 5-2, and 5-8**, respectively. The off-post explosives plume originates on the northeast edge of the CHAAP Facility (near LL1) and extends over 21,000 feet northeast into the surrounding rural and urban areas.

5.1.1 Off-Post Plume Extent

The off-post explosives groundwater plume consists primarily of RDX and HMX. TNT was only detected at two off-post well clusters (NW020 and CA350). Maximum concentrations detected off post during the March 2000 sampling event included 16 µg/L RDX (CA351), 7 µg/L HMX (CA351), and 25 µg/L TNT (NW020) (**Figure 5-1b**). TNT breakdown products (e.g., 2-Am-DNT and 4-Am-DNT) were also detected in the NW020, CA350 and CA380 well clusters. HMX has not been detected above health advisory levels off post or on post during any of the LTM events.

The axis of the off-post explosives plume trends from southwest to northeast (**Figure 5-1b**). The highest explosives concentrations were located near the facility boundary. Explosives concentrations declined to the northeast, dissipating near well cluster CA290. Low explosives concentrations were also detected in wells CA311 and CA312 (1.1 and 3.0 µg/L RDX, respectively) and CA342 (1.3 µg/L RDX).

March, 2000, March 1999, June 1998, October 1997, December 1996, and July 1994 RDX plume maps are shown on **Figures 5-2, 5-3, 5-4, 5-5, 5-6, and 5-7**, respectively. In general, RDX concentrations have declined from 1994 to 2000 at many of the off-post monitoring well clusters. For example, RDX concentrations (1994 and 2000 concentrations) have decreased at the well locations listed below; **Figure 5-11** presents these declining concentration trends.

- NW020 (from 26 to 12 µg/L)
- NW081 (from 17 to 5.4 µg/L)

- CA251 (from 28 to 5.6 µg/L)
- CA272 (from 15 to 4.3 µg/L)
- CA292 (from 5.85 µg/L to 0.59)

Table 5-1 summarizes the highest historical off-post explosives concentrations detected from 1984 to 2000. Data indicates RDX has declined over time from 1984 (>100 µg/L) and 1994 (28 µg/L) to the present (12 µg/L). TNT concentrations declined significantly from 1984 (>350 µg/L) to 1994 (23 µg/L). Since then, TNT concentrations have remained similar, ranging from 22.3 µg/L to 25 µg/L at NW020 (**Table 5-1** and **Figures 5-8 and 5-9**). This may be indicative of a residual source of TNT at LL1. The USACE has overseen the installation of an additional extraction well (EW-7) at the post boundary (see **Figure 1-1**) to contain on-post explosives contamination.

5.1.2 On-Post Plume Extent

The on-post explosives groundwater plumes (at Loadlines [LL] 1, 2, and 3) consist primarily of TNT, RDX, TNB, and HMX. Maximum concentrations detected during the March 2000 sampling event included 2500 µg/L TNT (PZ013 at LL2), 130 µg/L, RDX (PZ013 at LL2), 550 µg/L TNB (PZ012 at LL2), and 27 µg/L HMX (PZ013 at LL2). Explosive breakdown products including 2-Am-DNT, and 4-Am-DNT were also detected in 19 wells and piezometers sampled on post.

The on-post contamination was located mostly on the east sides of LL1, LL2, and LL3 (near the suspected source areas). Highest explosive concentrations were located at LL1 and LL2. No explosive concentrations were detected above the health advisory levels at LL4, LL5 or the nitrate area.

5.2 VERTICAL EXTENT OF GROUNDWATER PLUME

Interpreted vertical extent of the off-post explosives plume is shown on geologic cross-section A-A' (**Figure 5-12**). Although overall explosives concentrations have generally declined from December 1996 (W-C 1997a) to March 2000, the vertical extent and cross-sectional interpretation of the plume (to 2 µg/L) have remained similar. Contrasts in hydraulic properties between the Grand Island Formation (alluvial sand aquifer) and Fullerton Formation (alluvial clay aquitard) have continued to restrict the occurrence of groundwater contamination to the Grand Island Formation. Explosives were not detected in the deep aquifer (Holdrege Formation). The Fullerton Formation appears to act as a natural barrier, retarding the vertical migration of explosives to the underlying Holdrege Formation (gravel-paleovalley fill aquifer).

The plume was detected at depths of 7 to 57 feet bgs (i.e., from the water table to 50 feet below the water table). There appears to be a clean zone near the water table in the distal edges of the off-post plume, possibly due to infiltrating surface recharge.

5.3 NATURE AND EXTENT SUMMARY

In summary, the March 2000 sampling results indicated the following:

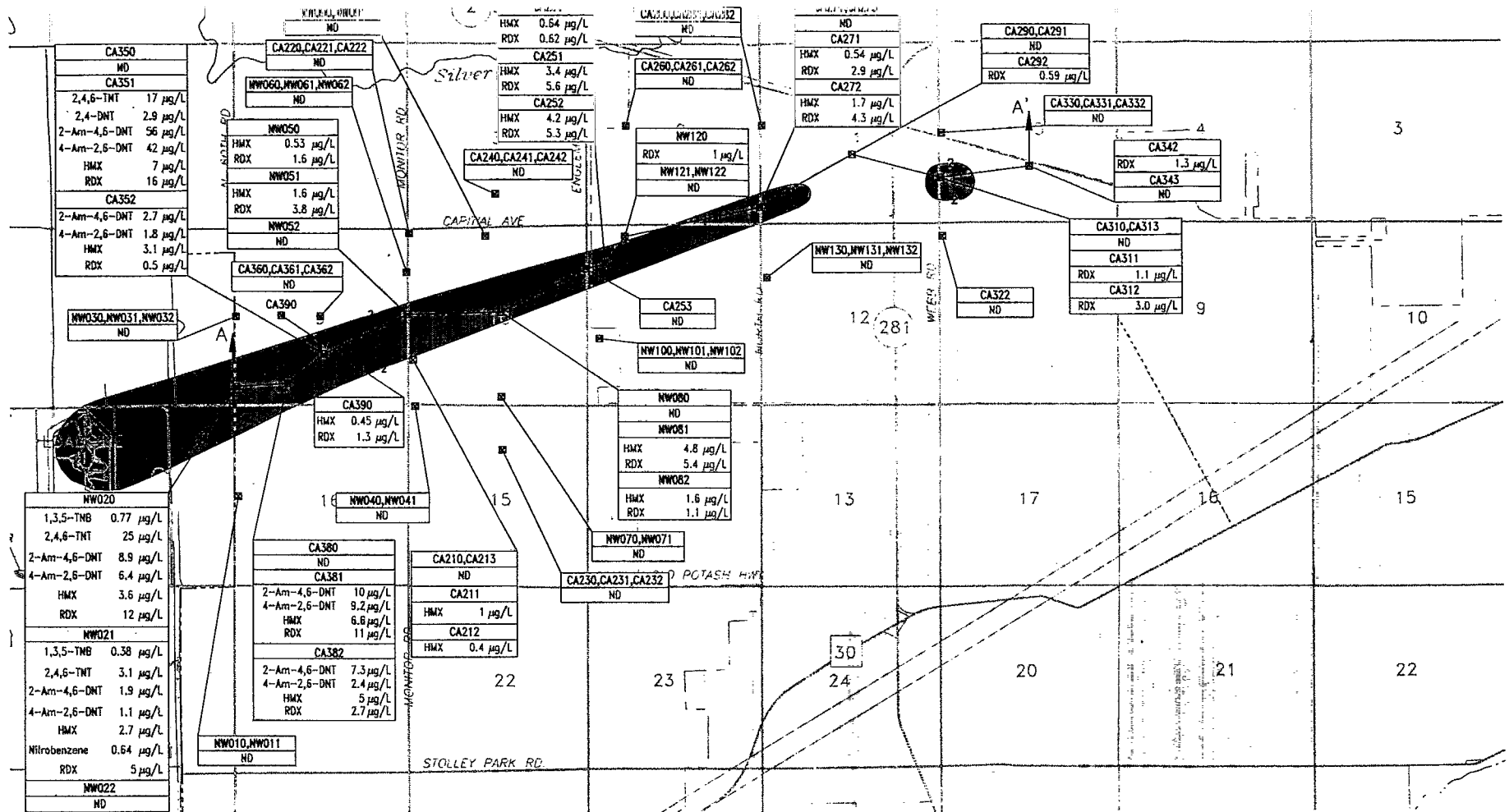
Off-Post Plume

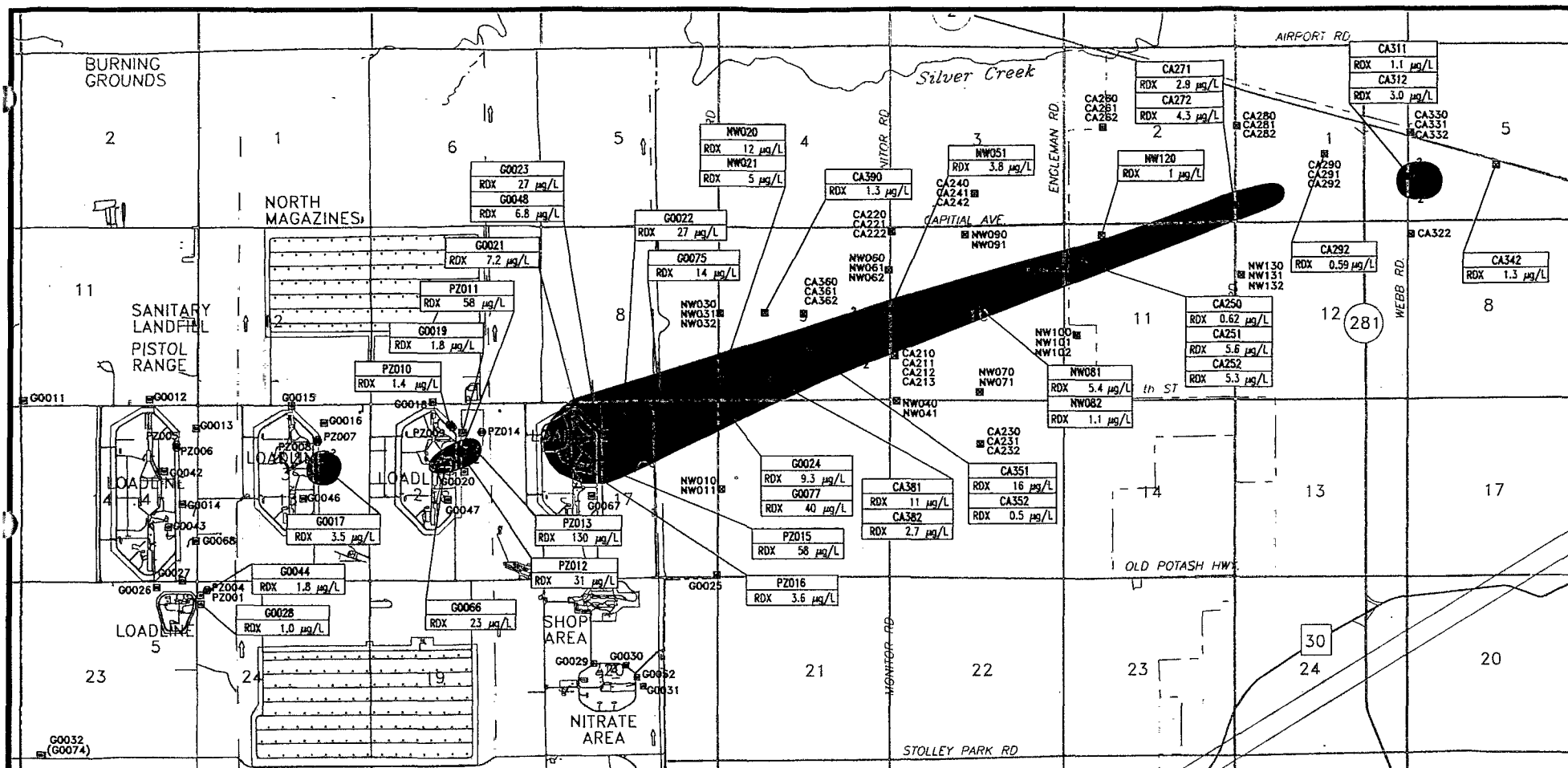
- The explosives plume, consisting primarily of RDX, is still present off post but is not migrating any further downgradient.
- Explosives concentrations within the off-post plume are declining over time.
- TNT breakdown products (e.g., 2-Am-DNT and 4-Am-DNT) have been detected in off-post monitoring well clusters NW020, CA350, and CA380.
- HMX has not been detected above the health advisory level (i.e., 400 µg/L) during any LTM sampling event.

Possible reasons for off-post explosives concentrations declining from 1984 (Spalding and Fulton 1988) to 2000 include natural attenuation processes (e.g., dispersion, biodegradation, and abiotic degradation), contaminant soil source removal and on-post groundwater extraction.

On-Post Source Areas

- RDX and TNT concentrations were significantly above health advisory levels at Loadlines 1, 2, and 3.
- On-post RDX and TNT concentrations near extraction wells EW-4, EW-5, and EW-6 have remained low. (Similar over the past three LTM monitoring events.)
- No explosives concentrations were detected above health advisory levels at LL4, LL5 and the nitrate area.
- HMX has not been detected above the health advisory level (i.e., 400 µg/L) during any LTM sampling event.





LEGEND:

- FACILITY BOUNDARY
- GRAND ISLAND CITY LIMITS
- ==> DRAINAGE DITCH FLOW DIRECTION
- - - - SURFACE DRAINAGE

(28) STATE ROUTE

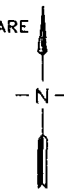
[50] U.S. ROUTE

- ON-POST GROUNDWATER MONITORING WELL
- OFF-POST GROUNDWATER MONITORING WELL
- ON-POST PIEZOMETER
- HORIZONTAL EXTENT OF RDX (CONCENTRATIONS >2µg/L)-MARCH 2000

NOTE:

- ON-POST AST/UST MONITORING WELLS AND MINIWELLS ARE NOT SHOWN.
- ALL OFF-POST MONITORING WELLS WERE SAMPLED AND ANALYZED FOR RDX. DETECTED RDX CONCENTRATIONS ARE SHOWN. ALL OTHER OFF-POST WELLS WERE "NON-DETECT" FOR RDX.

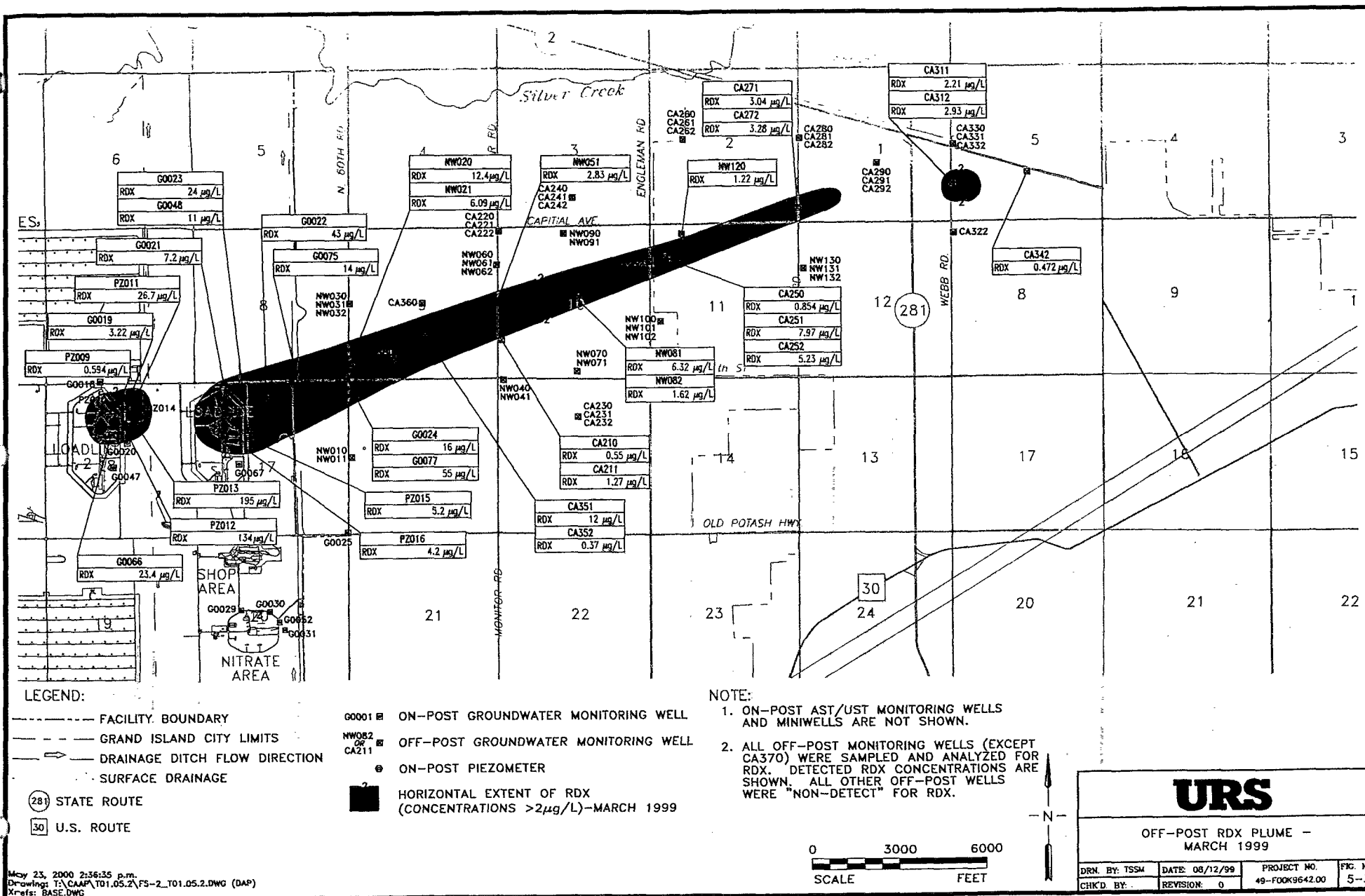
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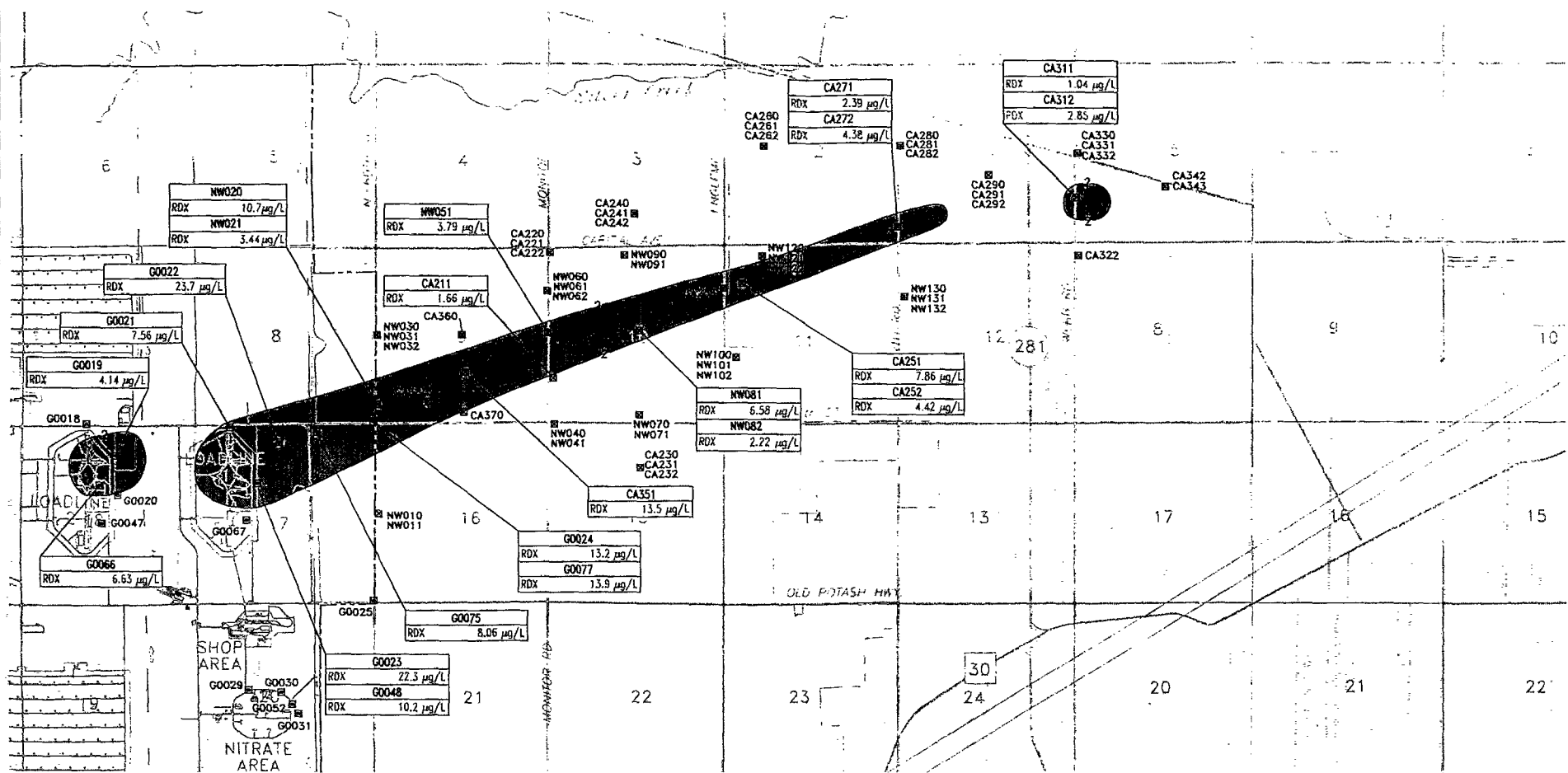


URS

RDX PLUME -
MARCH 2000

DRN. BY: DAP	DATE: 05/19/00	PROJECT NO. 49-F00K9642.00	FIG. NO. 5-2
CHK'D. BY:	REVISION: 0		





LEGEND:

- FACILITY BOUNDARY
- GRAND ISLAND CITY LIMITS
- DRAINAGE DITCH FLOW DIRECTION
- SURFACE DRAINAGE

(281) STATE ROUTE

(30) U.S. ROUTE

- G0001 ■ ON-POST GROUNDWATER MONITORING WELL
- NW082 ■ OFF-POST GROUNDWATER MONITORING WELL
- CA211 ■

■ HORIZONTAL EXTENT OF RDX
(CONCENTRATIONS >2µg/L)-JUNE 1998

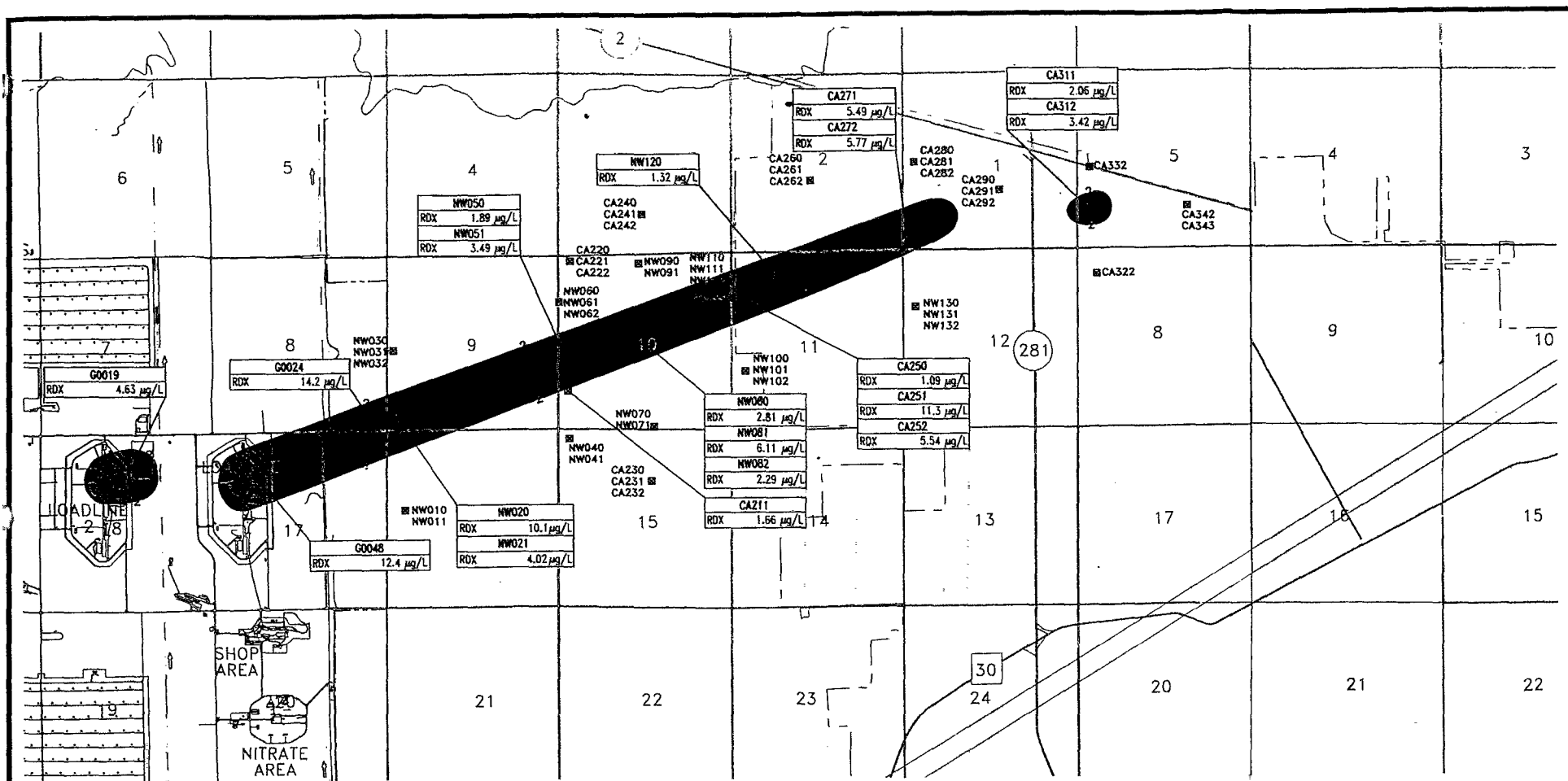
NOTE:

1. ON-POST AST/UST MONITORING WELLS AND MINIWELLS ARE NOT SHOWN.
2. ALL OFF-POST MONITORING WELLS WERE SAMPLED AND ANALYZED FOR RDX. DETECTED RDX CONCENTRATIONS ARE SHOWN. ALL OTHER OFF-POST WELLS WERE "NON-DETECT" FOR RDX.

May 23, 2000 2:34:41 p.m.
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Xrefs: BASE.DWG

0 3000 6000
SCALE FEET

URS			
OFF-POST RDX PLUME - JUNE 1998			
DRN BY: TSM	DATE: 06/12/99	PROJECT NO: 49-F00K9642.00	FIG NO: 5-4
CHK'D BY:	REVISION: 0		



LEGEND:

- FACILITY BOUNDARY
- GRAND ISLAND CITY LIMITS
- DRAINAGE DITCH FLOW DIRECTION
- SURFACE DRAINAGE

(28) STATE ROUTE

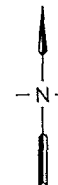
(30) U.S. ROUTE

G0001 ■ ON-POST GROUNDWATER MONITORING WELL
 NW082 ■ OFF-POST GROUNDWATER MONITORING WELL
 CA211 ■

■ HORIZONTAL EXTENT OF RDX
 (CONCENTRATIONS > 2 µg/L) - OCTOBER 1997

NOTE:
 ON-POST AST/UST MONITORING WELLS
 AND MINIWELLS ARE NOT SHOWN.

0 3000 6000
 SCALE FEET



URS

OFF-POST RDX PLUME -
 OCTOBER 1997

DRN. BY: TSM	DATE: 08/12/99	PROJECT NO.	FIG. NO.
CHKD. BY:	REVISION: 0	49-F00K9642.00	5-5



- 30 U.S. ROUTE

2

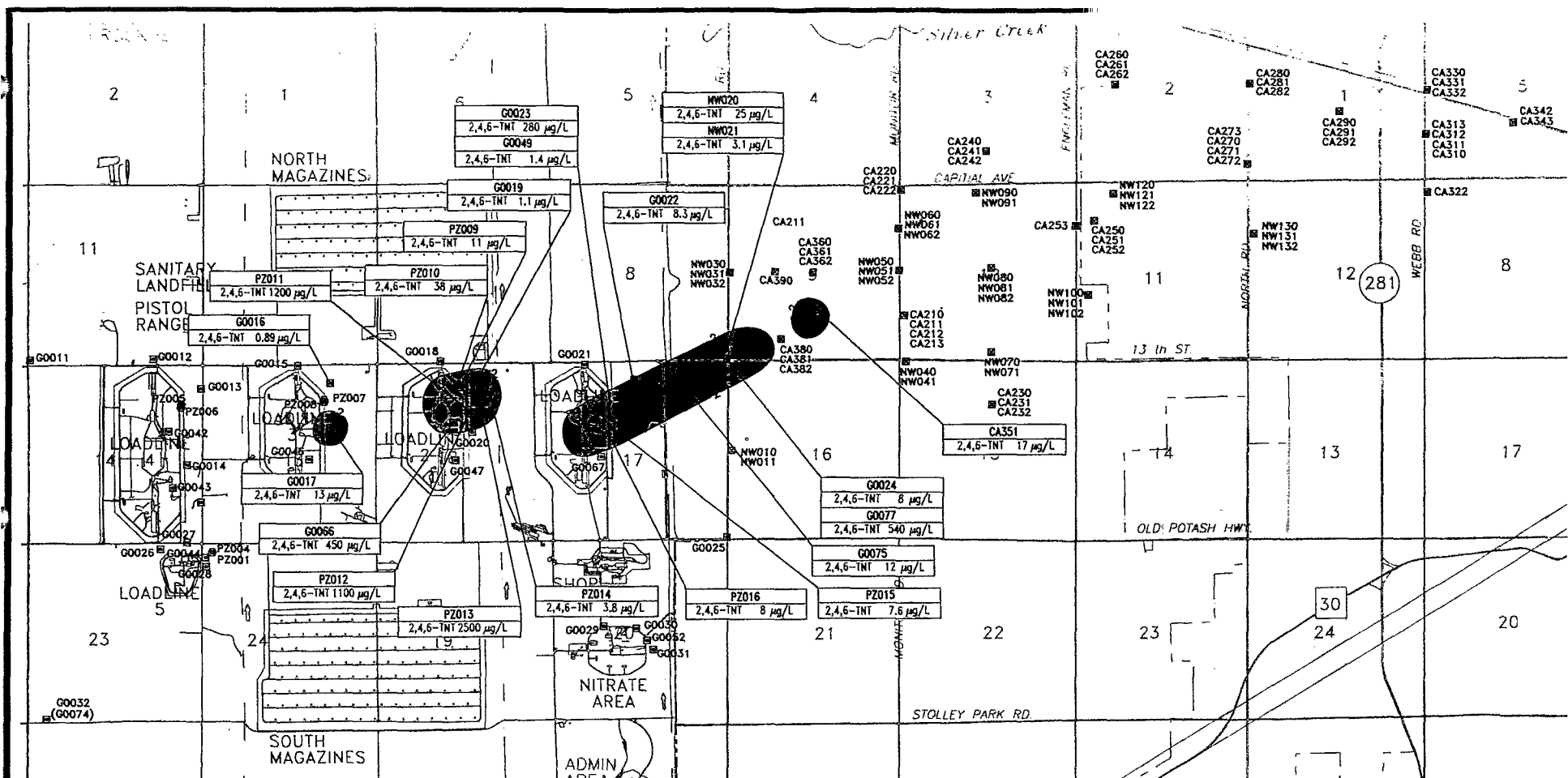
NOTE:

URS

OFF-POST RDX PLUME -
DECEMBER 1996

DRN. BY: TSSM	DATE: 08/12/99	PROJECT NO.	FIG. NO.
CHK'D. BY:	REVISION: 0	49-F00K9642.00	5-6

May 23, 2000 2:30:46 p.m.
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Xrefs: base.DWG



LEGEND:

- FACILITY BOUNDARY
- GRAND ISLAND CITY LIMITS
- > DRAINAGE DITCH FLOW DIRECTION
- SURFACE DRAINAGE

(281) STATE ROUTE

(30) U.S. ROUTE

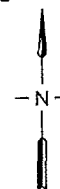
- G0001 ■ ON-POST GROUNDWATER MONITORING WELL
- NW082 ■ OFF-POST GROUNDWATER MONITORING WELL
- CA211 ■ ON-POST PIEZOMETER

■ HORIZONTAL EXTENT OF TNT
(CONCENTRATIONS > 2 µg/L) - MARCH 2000

NOTE:

1. ON-POST AST/UST MONITORING WELLS AND MINIWELLS ARE NOT SHOWN.
2. ALL OFF-POST MONITORING WELLS WERE SAMPLED AND ANALYZED FOR TNT. DETECTED TNT CONCENTRATIONS ARE SHOWN. ALL OTHER OFF-POST WELLS WERE "NON-DETECT" FOR TNT.

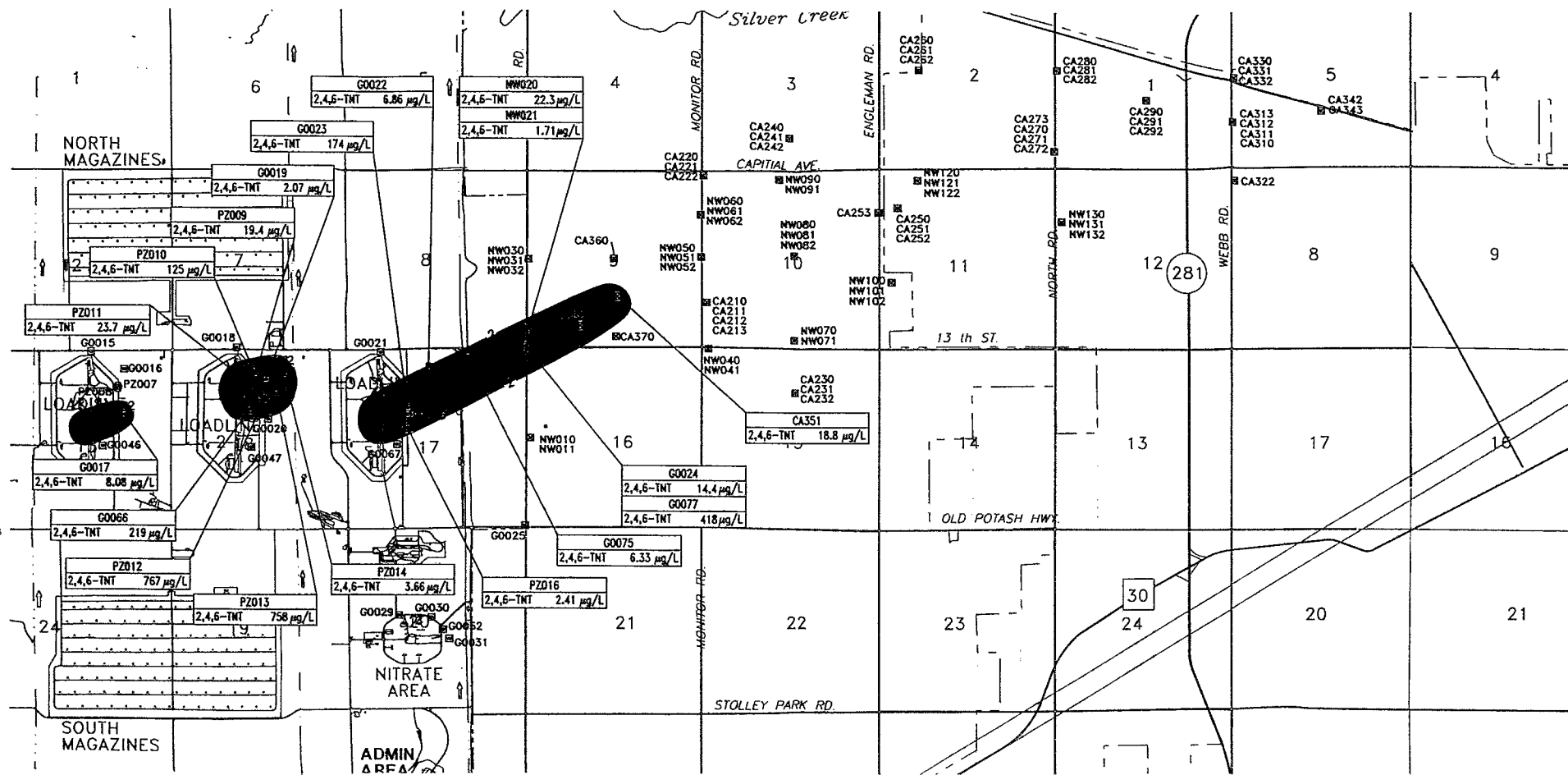
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SCALE FEET



URS

TNT PLUME - MARCH 2000

DRN. BY: DAP	DATE: 05/19/00	PROJECT NO. 49-F00K9642.00	FIG. NO. 5-B
CHKD. BY:	REVISION: 0		



LEGEND:

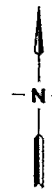
- FACILITY BOUNDARY
- GRAND ISLAND CITY LIMITS
- DRAINAGE DITCH FLOW DIRECTION
- SURFACE DRAINAGE
- (281) STATE ROUTE
- (30) U.S. ROUTE

- G0001 ■ ON-POST GROUNDWATER MONITORING WELL
- NW082 ■ OFF-POST GROUNDWATER MONITORING WELL
- CA211 ■ ON-POST PIEZOMETER
- HORIZONTAL EXTENT OF TNT (CONCENTRATIONS >2μg/L)-JUNE 1998

NOTE:

1. ON-POST AST/UST MONITORING WELLS AND MINIWELLS ARE NOT SHOWN.
2. ALL OFF-POST MONITORING WELLS WERE SAMPLED AND ANALYZED FOR TNT. DETECTED TNT CONCENTRATIONS ARE SHOWN. ALL OTHER OFF-POST WELLS WERE "NON-DETECT" FOR TNT.

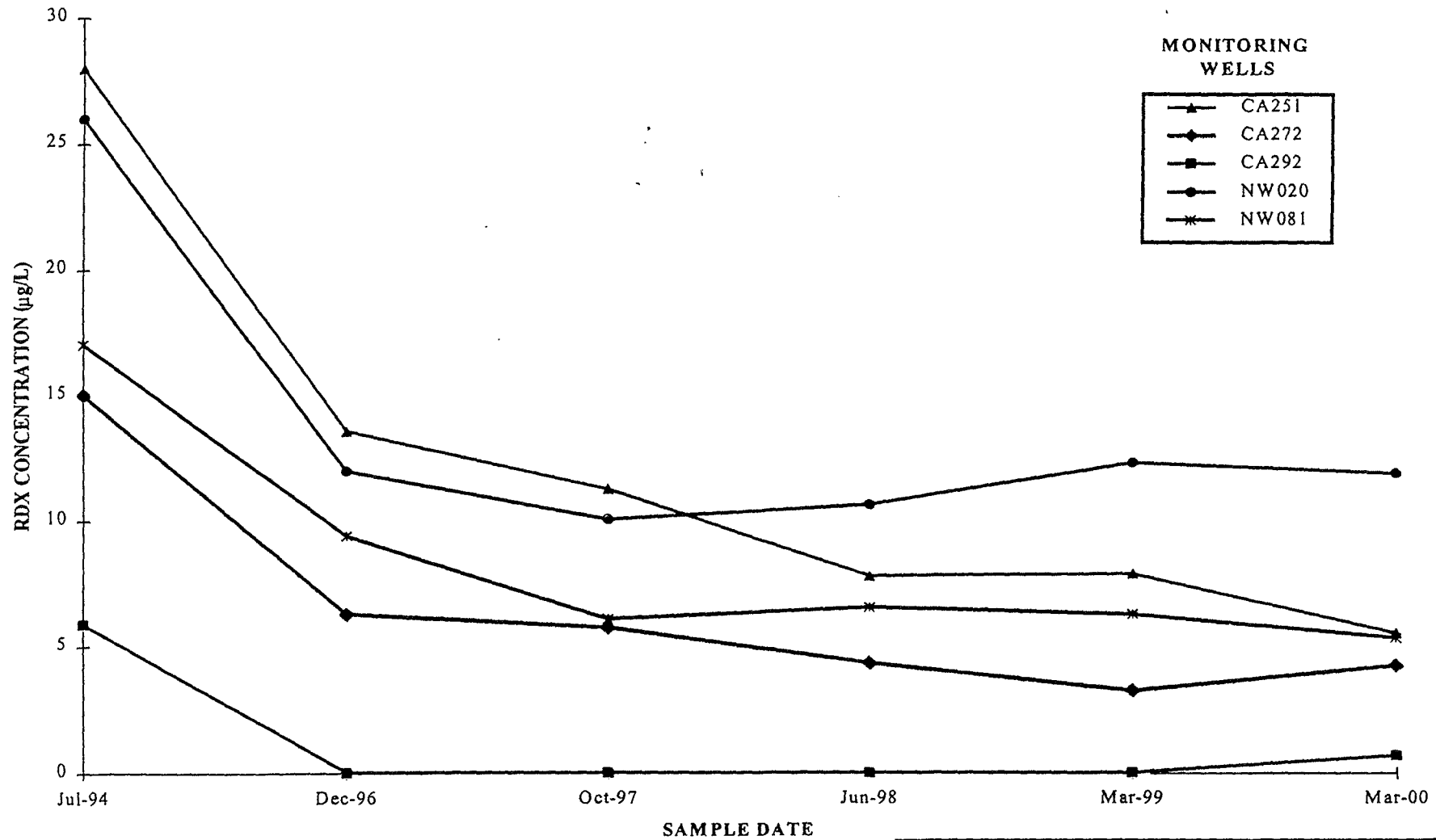
0 3000 6000
SCALE FEET



URS

TNT PLUME - JUNE 1998

DRN. BY: TSSM	DATE: 08/12/99	PROJECT NO.	FIG. NO
CHK'D. BY:	REVISION: 0	49-FOOK9642.00	5-10



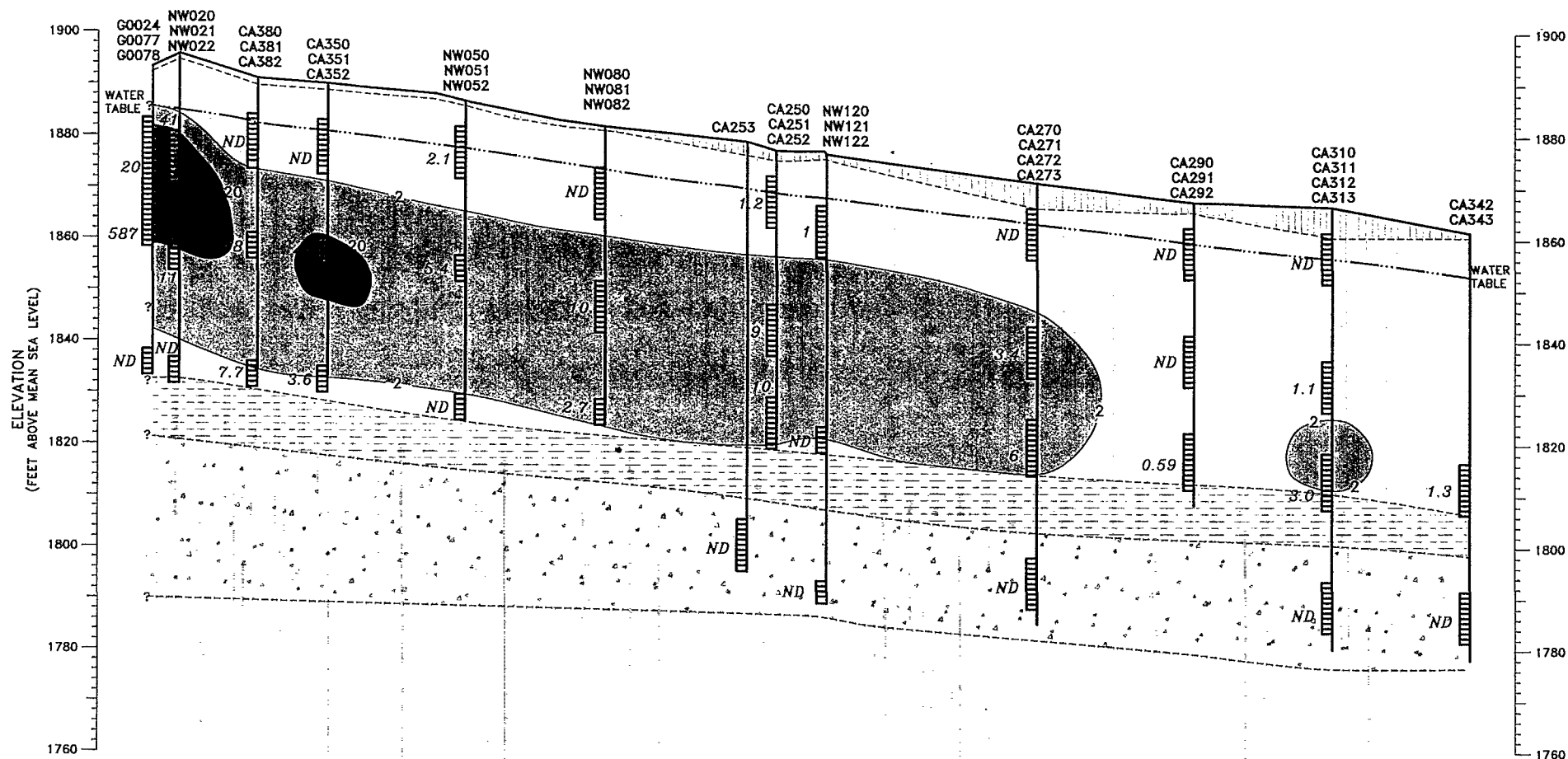
URS

RDX CONCENTRATION TRENDS IN SELECTED OFF-POST MONITORING WELLS

DRN BY: CA	DATE: 6/29/00	PROJECT NO.	FIG NO.
CHK'D BY:	DATE:	49F00K9642	5-11

A
SOUTHWEST

A'
NORTHEAST



LEGEND:

- MONITORING WELL SCREEN INTERVAL WITH MARCH 2000 TOTAL TARGET CLEANUP EXPLOSIVES CONCENTRATION (e.g., 2,4,6-TNT, RDX, AND HMX)
- TOPSOIL/CLAY AND SILT
- GRAND ISLAND FORMATION (ALLUVIAL SAND AQUIFER)
- FULLERTON FORMATION (BLUE CLAY AQUITARD)
- HOLDREGE FORMATION (GRAVEL-PALEOVALLEY FILL AQUIFER)
- WATER TABLE-MARCH 2000
- INTERPRETED VERTICAL AND HORIZONTAL EXTENT OF TARGET CLEANUP EXPLOSIVES (TOTAL CONCENTRATIONS > 2 µg/L)

June 27, 2000 8:59:06 a.m.
Drawing: T:\CAAP\T01.05.2\F5-9-2000.DWG (DAP)

URS

MARCH 2000 EXPLOSIVES
CONCENTRATIONS ALONG GEOLOGIC
CROSS-SECTION A-A'

DRN. BY: BAG	DATE: 05/22/00	PROJECT NO.	FIG. NO.
CHK'D. BY:	REVISION: 0	49-FOOK9642 00	5-12

TABLE 5-1

**HIGHEST HISTORICAL OFF-POST PLUME EXPLOSIVES CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Compound Detected (µg/L)	Highest Off-Post Concentrations¹					
	March 2000	March 1999	June 1998	Oct 1997	Dec 1996	July 1994
Cyclonite (RDX)	12 (16) ²	12.4 (12.0) ²	10.7 (13.5) ²	11.3	13.6	28
2,4,6-Trinitrotoluene (TNT)	25 (17) ²	34.9	22.3	22.8	30	23
Cyclotetramethylenetetranitramine (HMX)	4.8 (6.6) ²	3.8 (5.9) ²	4.3 (14.8) ²	4.07	4.9	9.54
1,3,5-Trinitrobenzene (TNB)	0.77	0.793	ND	1.24	1.2	1.54
2,4-Dinitrotoluene (2,4-DNT)	ND (2.8) ²	ND (2.4) ²	3.78	0.753	0.78	0.311
2-Amino-4,6-Dinitrotoluene (2-Am-DNT)	8.9 (56) ²	9.15 (42) ²	8.0 (53.4) ²	10.4	13	12
4-Amino-2,6-Dinitrotoluene (4-Am-DNT)	6.4 (42) ²	6.26 (33) ²	5.9 (49.4) ²	7.15	10.8	NA

¹ Includes off-post plume wells only.

² Concentrations measured in new feed lot well clusters (installed May 1998 and December 1999) were often higher than other off-post locations, and are shown in parentheses.

SECTION SIX**Natural Attenuation Evaluation**

This section presents a preliminary evaluation of natural attenuation of the off-post explosives plume at CHAAP. The evaluation was completed using laboratory analyses of water quality parameter data and field water quality parameter data measured during the last three LTM events (i.e., June 1998, March 1999, and March 2000), and explosives data from 1984 to 2000.

6.1 Natural Attenuation Evaluation Methodology

Natural attenuation can be an effective remedial option for contaminants in groundwater at CHAAP if it can be demonstrated that sufficient attenuation processes are occurring at a rate sufficient to protect human health and the environment. These *in-situ* processes include biodegradation, abiotic transformation, dispersion, organic carbon adsorption, and irreversible soil binding. The natural attenuation demonstration at CHAAP is being implemented in accordance with the protocols presented in the OSWER Directive “Use of Monitored Natural Attenuation at Superfund, RCRA, Corrective Action, and Underground Storage Tank Sites” (USEPA 1997), and “Draft Protocol for Evaluating, Selecting, and Implementing Monitored Natural Attenuation at Explosives-Contaminated Sites” (USACE WES 1999). The natural attenuation demonstration at CHAAP includes:

- Completing long-term groundwater monitoring in support of natural attenuation by monitoring key natural attenuation water quality parameters and explosives concentrations over time
- Identifying the significant natural attenuation processes occurring at the site, especially the processes which may be facilitating anaerobic degradation of the off-post explosives plume
- Determining the rate at which the natural attenuation processes are reducing contaminant concentrations

6.2 NATURAL ATTENUATION WATER QUALITY PARAMETER RESULTS

Tables 6-1 and 6-2 present key water quality parameter data, including laboratory parameters (i.e., nitrate+nitrite, ammonia, TKN, dissolved organic carbon, CO₂, alkalinity, sulfate, and sulfide) and field parameters (i.e., redox, dissolved oxygen, Fe²⁺, pH, and conductivity). The natural attenuation water quality parameter results are also shown on **Figures 6-1a through 6-1d**. These parameters are reported by Weidemeier et. al. (1996) and USACE WES (1999) to help identify anaerobic degradation processes commonly occurring at groundwater contamination sites. Explosives have been demonstrated to biodegrade under anaerobic/reducing conditions (USACE WES 1997, 1998).

Figures 6-2a through 6-4a present interpreted isoconcentrations of average redox potential, DO, and NO₃+NO₂ in shallow groundwater. **Figures 6-2b through 6-4b** present the same parameters plotted along a cross section down the center of the off-post explosives plume.

For purposes of comparison, the data has been evaluated and separated into three basic groups: general sitewide data (including background), off-post plume/on-post source area data, and feedlot area data.

6.2.1 General Sitewide Trends

General sitewide and background data trends include:

- Redox potentials within the Grand Island Formation aquifer off post were lower at the base of the aquifer than the water table and shallow-intermediate depths. Shallow wells averaged 170 mV, shallow-intermediate wells averaged 156 mV, and intermediate wells averaged 111 mV (**Table 6-1**).
- DO concentrations within the Grand Island Formation aquifer off post were generally lower at depth than at the water table surface. Shallow wells averaged about 3.8 mg/L, shallow-intermediate wells averaged 2.3 mg/L, and intermediate wells averaged 1.1 mg/L (**Table 6-1**).
- Fe^{2+} concentrations within the Grand Island Formation aquifer off post were negligible. Average values were 0.10 mg/L (shallow), 0.06 mg/L (shallow-intermediate), and 0.26 mg/L (intermediate) (**Table 6-1**).
- Within the deeper Holdrege Formation aquifer, redox potentials were low (average of -40 mV), DO values were low (average of 0.59 mg/L), and Fe^{2+} was consistently detected at low levels (average 0.53 mg/L).
- Many of the on-post natural attenuation parameter results (both field and laboratory) were inconclusive. The sporadic nature of the contaminant occurrences (isolated sources) make interpretation of the natural attenuation parameter results somewhat problematic.

6.2.2 Off-Post Plume/On-Post Source Area Trends

Most parameters were similar to the sitewide parameters, except in areas of higher contamination levels (mostly on-post at LL1 and LL2 and the feedlot area). The trends included:

- Redox potentials near the LL2 source were generally lower (averaging less than 100 mV) than background areas (greater than 100 mV) (see **Figure 6-2a**).
- DO concentrations near LL2 source area and within the off-post plume were generally lower (most below 2 mg/L) than background areas (greater than 2 mg/L) (see **Figure 6-3a**). There was an area of anomalously high DO concentrations within the LL1 source area. The increase in DO concentrations may be the result of the soil removal action completed in this area.
- On-post $\text{NO}_3 + \text{NO}_2$ concentrations were generally lower (less than 10 mg/L) in areas with significant explosives concentrations (e.g., near LL2) than in background areas (mostly greater than 10 mg/L) (see **Figure 6-4a**).
- Excluding the feedlot area, the interpretation of off-post plume area trends is currently inconclusive. Off-post explosives concentrations in the low $\mu\text{g/L}$ levels may not be high

enough to significantly alter the overall water chemistry of the aquifer, especially when the natural attenuation parameters are typically measured at mg/L levels.

6.2.3 Feedlot Area Trends

Most parameter results indicated the groundwater underlying and just downgradient of the feedlot area was significantly different than background areas and other off-post plume areas (see **Tables 6-1 and 6-2 and Figures 6-1 through 6-4**). The data indicates that the feedlot area has highly reducing conditions which appear to have facilitated anaerobic degradation processes. Significant trends were as follows:

- Redox potentials within the Grand Island Formation aquifer underlying and downgradient of the feedlot area were much lower than other areas. Shallow wells averaged -89 mV, shallow-intermediate wells averaged 3 mV, and intermediate wells averaged -58 mV (**Table 6-1**). **Figures 6-2a and 6-2b** indicate a zone of reducing conditions that extends from the water table surface to the base of the aquifer underneath the feedlot area.
- DO concentrations beneath the feedlot area were generally less than other areas (see **Figure 6-3a and 6-3b**). Shallow wells averaged about 0.81 mg/L, shallow-intermediate wells averaged 0.29 mg/L, and intermediate wells averaged 0.27 mg/L (**Table 6-1**).
- NO₃+NO₂ concentrations were significantly lower in the feedlot area (generally less than 1.0 mg/L) than other areas (mostly greater than 10 mg/L) (see **Figure 6-4a**). **Figure 6-4b** indicates NO₃+NO₂ concentrations lower than background throughout the water column in the feedlot area. Additionally, TKN and ammonia concentrations in the shallow feedlot wells (average values of 45.7 and 39.5 mg/L, respectively) were significantly elevated above other areas (average values of 0.14 mg/L and 0.10 mg/L, respectively). These differences indicate significant denitrification is occurring in the feedlot area.
- Fe²⁺ concentrations in the shallow feedlot wells (average 15.7 mg/L) were significantly higher than shallow wells in other areas (average 0.1 mg/L), indicating Fe³⁺ reduction is occurring in the feedlot area.
- Methane concentrations in the shallow feedlot wells (average 1,757 µg/L) are elevated above shallow wells in other areas (average 14.6 µg/L), indicating methanogenesis is occurring in the feedlot area.
- Alkalinity, CO₂, DOC, and conductivity values in the shallow feedlot wells (average 560 mg/L, 246 mg/L, 77.0 mg/L, and 1,924 mS/cm, respectively) were elevated above other areas (average 159 mg/L, 69.4 mg/L, 8.4 mg/L, and 700 mS/cm, respectively).

6.3 ANAEROBIC DEGRADATION PROCESSES IDENTIFICATION

The data indicates groundwater chemical conditions are favorable for anaerobic degradation to occur within the explosives plumes, especially in the feedlot area and near LL2. TNT degradation products (e.g., 2-Am-DNT and 4-Am-DNT) were present in samples collected in the on-post source areas and the off-post feedlot area. RDX degradation products (e.g., MNX, DNX,

and TNX) were detected by Spalding (1998) in the feedlot area. Spalding's (1998) report was included as Appendix F to the March 1999 Annual Report (URSGWCFS 1999).

Anaerobic degradation processes proceed in an order of preference based on the amount of energy yielded by the reaction. The order of preference is denitrification, Fe^{3+} reduction, sulfate reduction, and then methanogenesis (Stumm and Morgan 1981, Bouwer 1994). The data indicates that denitrification is the main anaerobic degradation process occurring in the feedlot area and near LL2. The other anaerobic degradation processes (e.g., Fe^{3+} reduction, sulfate reduction, and methanogenesis) are also occurring in the feedlot area, but to a lesser extent.

The conditions favoring denitrification at CHAAP include:

- Abundant supply of nitrate in the aquifer from fertilizer applications sitewide and urea at the feedlot
- High organic carbon content in the aquifer underlying the feedlot
- Anaerobic/reducing conditions in groundwater underlying the feedlot. Denitrification will occur at redox values as high as 740 mV (Bouwer 1994).
- Probable presence of denitrifying bacteria in the feedlot and potentially sitewide

6.4 DEGRADATION RATE ESTIMATION

As part of the natural attenuation evaluation at CHAAP, URS completed Groundwater Contaminant Fate and Transport Modeling (URSGWCFS 2000b). For the modeling evaluations, first-order decay rates were estimated for RDX, TNT, and HMX. Decay rate constants represent loss of contaminant mass due to biotic decay processes (e.g., biodegradation) and abiotic decay processes (e.g., hydrolysis and evaporation). The decay rates were estimated using the following three methods:

- Graves (1995) using single well estimates and concentrations over time
- Graves (1995) using multiple well estimates and concentrations along the groundwater flow path
- Buscheck and Alcantar (1995) using multiple well estimates and concentrations along the groundwater flow path

Decay rate constants were converted into degradation half-lives. **Table 6-3** presents the estimated degradation half-lives used to complete the fate and transport modeling. Methodology, data, and calculations used to estimate degradation half-lives are included in the modeling report (URSGWCFS 2000b). Half-lives were estimated for three separate geographic areas based on the spatial relationship to the explosives plume and the feedlot. Estimated average half-lives were as follows:

- LL 1 (source area): RDX – 5.7 years, TNT – 5.7 years, and HMX – 7.2 years
- Feedlot (off post): RDX – 4.3 years, TNT – 2.5 years, and HMX – 0.6 years
- Distal off-post plume: RDX – 8.9 years, and HMX – 8.0 years

Generally, the modeling results indicated, if continuing on-post sources are contained, the current contaminant concentrations in the off-post plume (feedlot and distal plume areas) may be degraded to below the target cleanup goals in less than 20 years without distal well pumping. This is a similar timeframe to that expected using the off-post pump-and-treat remedial action proposed in the ROD (e.g., 20 to 30 years). The half-life estimates for CHAAP are within the range of published literature values for explosives (USACE WES 1997, 1998, 1999).

6.5 NATURAL ATTENUATION SUMMARY

The preliminary evaluation indicates natural attenuation of explosives in groundwater may be occurring at CHAAP. The key elements that support the use of natural attenuation at CHAAP include:

- RDX and TNT concentrations in the off-post plume have decreased steadily over time.
- Significant denitrification is occurring in the feedlot area which is facilitating explosives degradation as the plume migrates through this area. The feedlot area subsurface zone is functioning as an *in-situ* anaerobic/reducing treatment cell.
- Explosives degradation products are present, including RDX degradation products (e.g., MNX, DNX, and TNX from Spalding [1998]) and TNT breakdown products (e.g., 2-Am-DNT and 4-Am-DNT).
- The fate and transport modeling results indicate off-post explosives plume is degrading at a sufficient rate to achieve cleanup goals within the timeframe expected using an off-post pump-and-treat remedial action.
- Other anaerobic degradation processes (e.g., Fe reduction, methanogenesis, and sulfate reduction) are also occurring in the feedlot area, but to a lesser extent.
- The on-post explosives soil source areas have been removed.
- No further migration of on-post explosives contamination is expected because groundwater explosives source areas will be contained with the on-post groundwater extraction system.

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Redox (mV)				DO (mg/L)				NO ₃ +NO ₂ (mg/L)				Ammonia (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells																
NW010	205	179	139	174	1.91	2.80	4.22	2.98	7.7	6.9	5.5	6.7	ND	ND	ND	ND
NW020	99	89	110	99	3.22	1.63	2.62	2.49	21.7	10.7	18.0	16.8	ND	ND	ND	ND
NW030	145	150	105	133	0.41	2.54	2.38	1.78	9.8	12.3	12.7	11.6	1.3	ND	ND	0.4
NW040	150	143	176	156	0.58	0.60	1.91	1.03	8.7	20.3	38.1	22.4	0.039	ND	ND	0.01
NW050	129	131	125	128	1.89	2.99	2.17	2.35	98.2	94.5	70.4	87.7	ND	ND	ND	ND
NW060	96	241	138	158	5.97	8.09	9.67	7.91	25.5	14.2	20.5	20.1	ND	ND	ND	ND
NW070	-4	240	47	94	0.29	1.35	0.17	0.60	ND	7.2	ND	2.4	0.072	ND	ND	0.02
NW080	185	295	204	228	6.77	6.64	8.00	7.14	45.5	35.7	35.6	38.9	ND	ND	ND	ND
NW090	128	219	129	159	2.66	0.94	1.72	1.77	25.8	26.8	12.1	21.6	0.11	ND	ND	0.04
NW100	249	302	184	245	4.16	4.69	4.98	4.61	80.7	72.2	89.1	80.7	0.033	ND	ND	0.01
NW120	40	105	110	85	0.57	0.44	0.35	0.45	6.5	7.1	8.9	7.5	1.48	2.05	1.29	1.61
NW130	166	302	145	204	5.97	5.66	7.60	6.41	10.1	6.6	8.3	8.3	ND	ND	ND	ND
CA210	151	261	168	193	1.85	2.52	1.55	1.97	67.0	60.4	47.6	58.3	0.024	ND	ND	0.01
CA220	175	175	106	152	1.03	2.59	3.13	2.25	7.8	6.9	7.5	7.4	0.026	ND	ND	0.01
CA230	142	225	149	172	3.67	6.25	5.69	5.20	21.9	24.1	12.2	19.4	0.053	ND	ND	0.02
CA240	224	312	161	232	6.21	8.01	9.89	8.04	71.9	48.0	40.4	53.4	0.052	ND	ND	0.02
CA250	194	317	155	222	6.26	4.75	6.40	5.80	15.2	18.5	16.2	16.6	ND	ND	ND	ND
CA260	172	319	152	214	3.68	5.18	5.89	4.92	23.9	15.0	12.1	17.0	0.071	ND	ND	0.02
CA270	181	231	149	187	2.59	1.83	2.88	2.43	6.8	4.4	5.6	5.6	ND	ND	ND	ND
CA280	132	221	163	172	5.41	7.34	8.12	6.96	7.2	1.9	2.4	3.8	ND	ND	ND	ND
CA290	206	300	159	222	4.25	3.57	5.14	4.32	30.1	26.6	36.9	31.2	0.19	ND	ND	0.06
CA310	-22	216	113	102	1.78	2.31	3.60	2.56	4.9	9.8	NS	7.4	0.045	ND	NS	0.02
CA330	111	289	124	175	2.11	4.80	6.14	4.32	5.7	5.8	4.9	5.5	ND	ND	ND	ND
Ave	141	229	140	170	3.18	3.81	4.53	3.84	26.2	23.2	22.9	23.9	0.15	0.09	0.06	0.10
Shallow Feedlot Wells																
CA350	-72	-66	-68	-69	1.06	0.30	0.37	0.58	0.2	ND	1.5	0.6	0.245	0.177	0.431	0.28
CA360	-169	-164	-161	-165	3.47	0.22	0.29	1.33	ND	ND	ND	ND	88.3	93.4	72.2	84.6
CA370	-148	NS	NS	-148	0.98	NS	NS	0.98	ND	NS	NS	ND	29.5	NS	NS	29.5
CA380	-147	-150	-143	-147	2.01	0.25	0.27	0.84	ND	ND	ND	ND	66.8	94.5	86.8	82.7
CA390	NS	NS	85	85	NS	NS	0.32	0.32	ND	NS	7.6	7.6	NS	NS	0.531	0.53
Ave	-134	-127	-72	-89	1.88	0.26	0.31	0.81	0.1	ND	2.3	1.6	46.2	62.7	40.0	39.5

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Redox (mV)				DO (mg/L)				NO ₃ +NO ₂ (mg/L)				Ammonia (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow-Int Wells																
NW011	81	281	122	161	0.30	2.79	1.20	1.43	3.0	3.2	5.6	3.9	ND	ND	ND	ND
NW021	41	220	76	112	4.97	0.72	0.27	1.99	2.5	1.4	0.6	1.5	ND	ND	ND	ND
NW031	-35	46	-28	-6	0.13	0.40	0.25	0.26	0.2	ND	ND	0.1	ND	ND	ND	ND
NW041	193	200	116	170	0.28	0.69	0.40	0.46	6.2	12.8	5.8	8.2	ND	ND	ND	ND
NW051	182	209	42	144	0.51	0.30	0.29	0.37	30.5	28.8	32.2	30.5	0.035	ND	ND	0.01
NW061	116	85	60	87	0.19	0.47	0.17	0.28	ND	ND	ND	ND	0.16	0.251	ND	0.14
NW071	146	197	134	159	1.69	1.19	1.79	1.56	11.9	13.4	12.9	12.7	ND	ND	ND	ND
NW081	172	225	206	201	1.90	2.43	3.12	2.48	35.5	34.7	44.6	38.3	ND	ND	ND	ND
NW091	58	139	87	95	0.18	0.34	0.48	0.33	ND	ND	ND	ND	ND	ND	ND	ND
NW101	171	220	168	186	0.13	0.38	0.12	0.21	41.2	58.1	45.9	48.4	0.093	ND	ND	0.03
NW131	181	240	157	193	3.36	3.56	3.46	3.46	20.9	19.5	21.7	20.7	ND	ND	ND	ND
CA211	109	107	141	119	0.43	0.43	0.39	0.42	30.5	31.4	37.6	33.2	ND	ND	ND	ND
CA221	174	179	77	143	0.19	0.35	0.22	0.25	1.5	2.4	2.0	1.9	ND	ND	ND	ND
CA231	198	226	139	188	3.13	3.70	5.10	3.98	26.1	23.3	19.3	22.9	0.053	ND	ND	0.02
CA241	181	155	150	162	3.24	5.15	6.47	4.95	24.0	23.0	26.7	24.6	ND	ND	ND	ND
CA251	193	218	164	192	5.42	5.30	5.87	5.53	21.2	20.4	20.8	20.8	ND	ND	ND	ND
CA261	227	211	155	198	4.01	5.70	5.61	5.11	57.1	26.7	31.0	38.3	ND	ND	ND	ND
CA271	192	250	154	199	3.41	3.43	4.47	3.77	10.9	9.2	12.0	10.7	ND	ND	ND	ND
CA281	175	291	164	210	2.39	2.44	4.57	3.13	11.7	11.5	12.5	11.9	ND	ND	ND	ND
CA291	125	227	167	173	2.97	4.47	6.30	4.58	19.4	27.6	24.7	23.9	0.026	ND	ND	0.01
CA311	85	255	127	156	4.27	1.89	2.85	3.00	13.6	12.5	14.6	13.6	ND	ND	ND	ND
CA331	154	265	131	183	3.07	3.47	4.56	3.70	13.0	12.4	14.0	13.1	0.032	ND	ND	0.01
Ave	142	202	123	156	2.10	2.25	2.63	2.33	17.3	16.9	17.5	17.2	0.02	0.01	ND	0.01
Shallow-Int Feedlot Wells																
CA351	69	76	79	75	0.75	0.17	0.32	0.41	2.7	1.9	1.5	2.0	0.05	ND	ND	0.02
CA361	NS	NS	-163	-54	NS	NS	0.25	0.25	NS	NS	ND	ND	NS	NS	59.2	59.2
CA381	NS	NS	-36	-12	NS	NS	0.21	0.21	NS	NS	ND	ND	NS	NS	4.48	4.48
Ave	69	76	-40	3	0.75	0.17	0.26	0.29	2.7	1.9	0.5	0.7	0.1	ND	21.2	21.2

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Redox (mV)				DO (mg/L)				NO ₃ +NO ₂ (mg/L)				Ammonia (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Intermediate Wells																
NW022	-108	-59	-63	-77	0.33	0.36	0.35	0.35	ND	ND	ND	ND	ND	ND	ND	ND
NW032	-103	-54	-98	-85	0.67	0.50	0.33	0.50	ND	ND	ND	ND	0.052	ND	ND	0.02
NW052	-132	-112	-83	-109	0.20	0.27	0.25	0.24	ND	ND	ND	ND	ND	ND	ND	ND
NW062	204	-100	-84	7	0.42	0.29	0.26	0.32	ND	ND	ND	ND	ND	0.365	0.201	0.19
NW082	209	235	118	187	0.59	0.80	0.34	0.58	28.0	27.2	40.0	31.7	ND	ND	ND	ND
NW102	156	240	158	185	0.94	1.34	1.38	1.22	34.4	34.1	31.6	33.4	ND	ND	ND	ND
NW121	-63	76	65	26	0.64	0.36	0.25	0.42	1.1	ND	ND	0.4	ND	ND	ND	ND
NW132	187	231	147	188	0.82	0.53	1.29	0.88	25.4	25.8	35.7	29.0	ND	ND	ND	ND
CA212	74	227	85	129	0.63	0.28	0.20	0.37	13.0	8.9	13.3	11.7	ND	ND	ND	ND
CA222	-41	-13	-43	-32	0.09	0.50	0.23	0.27	ND	ND	ND	ND	ND	ND	ND	ND
CA232	115	256	128	166	2.65	3.96	3.92	3.51	8.6	8.3	9.1	8.7	ND	ND	ND	ND
CA242	161	262	128	184	0.51	0.40	0.50	0.47	1.2	2.1	2.4	1.9	ND	ND	ND	ND
CA252	252	295	154	234	0.89	0.61	0.77	0.76	21.3	19.2	20.1	20.2	ND	ND	ND	ND
CA262	162	248	137	182	0.87	1.98	2.02	1.62	9.1	12.8	10.5	10.8	0.032	ND	ND	0.01
CA272	191	212	100	168	0.40	0.49	1.12	0.67	6.6	6.3	8.8	7.2	ND	ND	ND	ND
CA282	93	215	149	152	1.59	2.41	3.41	2.47	16.9	14.9	12.5	14.8	ND	ND	ND	ND
CA292	115	247	157	173	0.42	0.31	1.16	0.63	7.4	6.3	6.2	6.7	ND	ND	ND	ND
CA312	149	216	109	158	0.83	1.25	2.30	1.46	12.0	11.1	12.5	11.9	ND	ND	ND	ND
CA322	162	269	141	191	1.92	2.14	2.51	2.19	15.4	15.1	15.5	15.3	0.078	ND	ND	0.03
CA332	107	238	123	156	2.31	1.80	1.57	1.89	10.7	9.3	9.5	9.8	ND	ND	ND	ND
CA342	104	211	110	142	2.31	1.69	2.29	2.10	14.7	15.4	14.1	14.7	ND	ND	ND	ND
Ave	95	159	78	111	0.95	1.06	1.26	1.09	10.7	10.3	11.5	10.9	0.01	0.02	0.01	0.01
Int Feedlot Wells																
CA352	-64	-80	-46	-63	0.59	0.24	0.28	0.37	ND	ND	ND	ND	0.03	ND	ND	0.01
CA362	NS	NS	-140	-140	NS	NS	0.20	0.20	NS	NS	ND	ND	NS	NS	5.5	5.5
CA382	NS	NS	28	28	NS	NS	0.24	0.24	NS	NS	ND	ND	NS	NS	ND	ND
Ave	-64	-80	-53	-58	0.59	0.24	0.24	0.27	0.0	0.0	0.0	0.0	0.0	ND	1.8	1.8

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Redox (mV)				DO (mg/L)				NO ₃ +NO ₂ (mg/L)				Ammonia (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Deep Wells																
NW122	-111	-71	-101	-94	0.58	0.30	0.29	0.39	1.0	ND	ND	0.3	0.85	ND	ND	0.28
CA213	-129	-79	-82	-97	0.15	0.35	0.19	0.23	ND	ND	ND	ND	ND	ND	ND	ND
CA253	-79	-53	-82	-71	0.07	0.23	0.24	0.18	ND	ND	ND	ND	0.11	ND	ND	0.04
CA273	-83	-58	-121	-87	0.17	1.38	0.21	0.59	ND	ND	ND	ND	0.071	ND	ND	0.02
CA313	-42	-31	-94	-56	0.51	0.73	0.25	0.50	ND	ND	ND	ND	0.026	0.112	0.232	0.12
CA343	97	267	128	164	1.32	2.27	1.30	1.63	11.1	11.5	11.7	11.4	ND	ND	ND	ND
Ave	-58	-4	-59	-40	0.47	0.88	0.41	0.59	2.0	1.9	2.0	2.0	0.18	0.02	0.04	0.08

Notes:

DO - Dissolved Oxygen

TKN - Total Kjeldahl Nitrogen

NO₂+NO₃ - Nitrate plus NitriteCO₂ - Carbon Dioxide

DOC - Dissolved Organic Carbon

NS - Not Sampled

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	TKN (mg/L)				DOC (mg/L)				CO ₂ (mg/L)				Methane (ug/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells																
NW010	ND	ND	0.160	0.05	12.6	7.2	ND	6.6	54.6	52.8	44.4	50.6	ND	ND	ND	ND
NW020	ND	ND	ND	ND	8.4	9.0	7.5	8.3	99.0	124	127	116.7	ND	ND	ND	ND
NW030	1.24	ND	0.112	0.45	9.5	ND	ND	3.2	50.6	71.3	67.8	63.2	274	ND	ND	91
NW040	ND	ND	0.278	0.09	5.6	11.6	6.8	8.0	14.1	15.4	17.7	15.7	1.23	ND	ND	0.41
NW050	ND	ND	0.159	0.05	8.7	12.2	5.2	8.7	60.3	62.5	71.3	64.7	ND	ND	ND	ND
NW060	0.042	ND	ND	0.01	6.9	12.1	ND	6.3	17.5	19.8	19.9	19.1	1.43	127	ND	42.81
NW070	0.89	ND	2.67	1.19	15.6	19.8	7.8	14.4	43.8	75.2	73.5	64.2	133	157	210	167
NW080	ND	ND	ND	ND	8.3	14.7	ND	7.7	34.6	42.2	37.8	38.2	ND	ND	ND	ND
NW090	ND	ND	0.214	0.07	16.5	13.0	6.2	11.9	79.6	71.7	84.5	78.6	41.2	33.8	16	30.3
NW100	ND	ND	ND	ND	7.1	8.1	ND	5.1	18.3	11.0	11.1	13.5	ND	ND	ND	ND
NW120	ND	1.07	1.36	0.81	8.8	6.5	13.5	9.6	52.8	65.6	66.7	61.7	ND	ND	ND	ND
NW130	ND	ND	0.132	0.04	12.4	15.8	ND	9.4	56.3	62.5	85.4	68.1	ND	ND	ND	ND
CA210	ND	ND	ND	ND	13.9	9.9	15.2	13.0	70.4	94.2	102	88.9	ND	ND	ND	ND
CA220	0.036	ND	ND	0.01	6.5	12.0	ND	6.2	169	208	91.5	156.2	3.6	2.91	ND	2.17
CA230	ND	ND	0.155	0.05	13.8	15.1	6.4	11.8	42.9	28.6	40.0	37.2	ND	ND	ND	ND
CA240	ND	ND	ND	ND	7.0	9.5	ND	5.5	13.3	29.0	37.8	26.7	ND	ND	ND	ND
CA250	ND	ND	0.113	0.04	7.6	ND	ND	2.5	55.0	68.6	71.3	65.0	ND	ND	ND	ND
CA260	ND	ND	ND	ND	5.1	16.4	ND	7.2	27.5	44.4	61.2	44.4	1.03	ND	ND	0.34
CA270	ND	ND	0.221	0.07	7.5	12.3	6.2	8.7	78.3	58.1	65.6	67.3	ND	ND	ND	ND
CA280	ND	ND	0.235	0.08	6.4	14.7	ND	7.0	22.2	22.4	17.8	20.8	ND	ND	ND	ND
CA290	ND	ND	0.118	0.04	7.4	18.1	ND	8.5	102	90.2	68.6	86.9	ND	ND	ND	ND
CA310	0.30	ND	NS	0.15	9.7	20.5	NS	15.1	191	158	NS	174.5	1.22	ND	0.98	0.73
CA330	0.050	ND	ND	0.02	7.8	17.3	ND	8.4	168	196	161	175.0	ND	ND	ND	ND
Ave	0.11	0.05	0.27	0.14	9.3	12.0	3.4	8.4	66.1	72.7	64.7	69.4	19.86	13.94	9.87	14.56
Shallow Feedlot Wells																
CA350	1.09	1.20	1.65	1.31	15.7	14.8	18.8	16.4	169	200	171	180	245	953	720	639
CA360	83.3	100	93.8	92.4	163.0	169.0	157.2	163.1	390	500	222	371	3150	2350	2300	2600
CA370	45.1	NS	NS	45.1	23.0	NS	NS	23.0	276	NS	NS	276	3160	NS	NS	3160
CA380	76.1	98.4	90.6	88.4	68.7	88.2	103.6	86.8	349	407	183	313	3860	1790	1500	2383
CA390	NS	NS	1.51	1.5	NS	NS	18.7	18.7	NS	NS	92.4	92.4	NS	NS	ND	ND
Ave	51.4	66.5	46.9	45.7	67.6	90.7	74.6	77.0	296	369	167	246.4	2604	1698	1130	1757

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	TKN (mg/L)				DOC (mg/L)				CO ₂ (mg/L)				Methane (ug/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow-Int Wells																
NW011	0.036	ND	ND	0.01	6.3	9.1	ND	5.1	66.4	71.3	68.6	68.8	6.01	ND	ND	2.00
NW021	ND	ND	0.470	0.16	3.9	ND	6.5	3.5	99.0	103	96.4	99.5	ND	ND	ND	ND
NW031	0.17	ND	0.198	0.12	5.3	ND	ND	1.8	122	129	112	121.0	1.01	ND	0.43	0.48
NW041	ND	ND	0.1	0.03	5.2	7.2	ND	4.1	73.0	73.9	74.4	73.8	ND	ND	ND	ND
NW051	ND	ND	0.132	0.04	8.1	8.2	5.0	7.1	97.7	102	104	101.2	ND	ND	ND	ND
NW061	1.27	1.53	ND	0.93	19.1	23.8	18.5	20.5	155	169	165	163.0	127	158	23	102.7
NW071	ND	ND	ND	ND	7.2	16.9	ND	8.0	59.8	61.6	59.0	60.1	ND	ND	ND	ND
NW081	ND	ND	0.115	0.04	11.2	15.5	ND	8.9	96.1	78.8	75.7	83.5	ND	ND	ND	ND
NW091	0.38	ND	0.728	0.37	16.7	14.8	6.4	12.6	117	120	109	115.3	11.7	12.5	ND	8.1
NW101	ND	ND	0.100	0.03	9.3	7.1	6.5	7.6	59.4	54.5	51.0	55.0	ND	ND	ND	ND
NW131	ND	ND	0.250	0.08	10.0	16.0	6.0	10.7	36.7	39.6	61.2	45.8	ND	ND	ND	ND
CA211	ND	ND	ND	ND	7.9	8.3	ND	5.4	82.3	87.1	82.7	84.0	ND	ND	ND	ND
CA221	0.20	ND	0.268	0.16	6.2	16.3	ND	7.5	77.4	81.0	80.5	79.6	45.5	46.2	24	38.6
CA231	ND	ND	0.107	0.04	12.0	18.5	5.6	12.0	37.6	36.1	32.3	35.3	ND	ND	ND	ND
CA241	0.03	ND	0.297	0.11	7.4	7.3	ND	4.9	45.8	40.9	37.8	41.5	ND	ND	ND	ND
CA251	ND	ND	0.113	0.04	6.9	ND	ND	2.3	62.0	68.6	60.7	63.8	ND	ND	ND	ND
CA261	ND	ND	ND	ND	2.9	15.8	ND	6.2	49.7	48.0	43.3	47.0	ND	ND	ND	ND
CA271	ND	ND	0.373	0.12	5.4	16.5	ND	7.3	71.3	58.1	48.8	59.4	1.2	ND	ND	0.4
CA281	ND	ND	0.165	0.06	7.5	14.5	ND	7.3	51.9	48.0	40.0	46.6	ND	ND	ND	ND
CA291	0.037	ND	0.347	0.13	3.8	14.4	ND	6.1	39.7	48.4	41.1	43.1	ND	ND	ND	ND
CA311	ND	ND	0.235	0.08	6.6	15.3	ND	7.3	127	118	116	120.3	ND	ND	ND	ND
CA331	0.069	ND	ND	0.02	6.8	18.2	ND	8.3	75.7	70.8	60.3	68.9	ND	ND	ND	ND
Ave	0.10	0.07	0.18	0.12	8.0	12.0	2.5	7.5	77.4	77.6	73.6	76.2	8.75	9.85	2.16	6.92
Shallow-Int Feedlot Wells																
CA351	0.615	0.825	0.453	0.63	9.3	9.9	10.2	9.8	132	147	117	132	ND	ND	ND	ND
CA361	NS	NS	73.7	73.7	NS	NS	159.6	159.6	NS	NS	194	194	NS	NS	2300	2300
CA381	NS	NS	4.79	4.79	NS	NS	14.9	14.9	NS	NS	107	107	NS	NS	NS	NS
Ave	0.62	0.83	26.31	26.37	9.3	9.9	61.6	61.4	132	147	139	144	ND	ND	1150	1150

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	TKN (mg/L)				DOC (mg/L)				CO ₂ (mg/L)				Methane (ug/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Intermediate Wells																
NW022	ND	ND	0.406	0.14	3.0	11.4	5.9	6.8	103	96.8	100	99.9	1.32	ND	0.64	0.65
NW032	03.1	ND	0.294	0.20	5.9	ND	ND	2.0	113	113	117	114.3	1.4	ND	0.88	0.76
NW052	0.225	ND	0.895	0.37	10.7	10.9	5.4	9.0	118	117	122	119.0	28.4	29.7	32	30.0
NW062	1.58	2.55	2.08	2.07	23.5	32.6	16.8	24.3	185	207	161	184.3	2010	573	450	1011
NW082	ND	ND	0.118	0.04	7.9	14.1	ND	7.3	98.6	94.4	95.5	96.2	ND	ND	ND	ND
NW102	ND	ND	ND	ND	8.9	5.9	ND	4.9	50.2	47.1	45.3	47.5	ND	ND	ND	ND
NW121	0.34	ND	0.591	0.31	10.2	ND	18.2	9.5	94.2	80.1	156	110.1	ND	ND	ND	ND
NW132	ND	ND	ND	ND	10.0	15.4	5.5	10.3	53.7	51.5	45.3	50.2	ND	ND	ND	ND
CA212	ND	ND	0.161	0.05	8.1	8.0	ND	5.4	105	97.7	90.6	97.8	ND	ND	ND	ND
CA222	0.036	ND	0.658	0.23	7.2	11.0	ND	6.1	94.2	97.2	92.8	94.7	87.5	95	82	88.2
CA232	ND	ND	ND	ND	10.9	25.4	5.4	13.9	50.2	51.5	51.0	50.9	ND	ND	0.29	0.10
CA242	ND	ND	0.106	0.04	7.1	ND	ND	2.4	81.8	80.5	78.8	80.4	1.16	ND	ND	0.39
CA252	0.03	ND	0.102	0.04	7.2	11.7	5.9	8.3	93.3	95.9	91.1	93.4	ND	ND	ND	ND
CA262	ND	ND	ND	ND	4.7	14.3	ND	6.3	95.9	102	94.6	97.5	1.13	ND	ND	0.38
CA272	ND	ND	0.373	0.12	5.1	16.1	7.2	9.5	75.2	74.4	75.7	75.1	ND	ND	ND	ND
CA282	ND	ND	0.176	0.16	5.7	17.7	ND	7.8	56.8	55.9	53.2	55.3	ND	ND	ND	ND
CA292	ND	ND	0.159	0.05	4.0	9.7	ND	4.6	63.4	65.1	65.6	64.7	ND	ND	ND	ND
CA312	0.050	ND	ND	0.02	6.1	15.7	ND	7.3	68.2	79.6	75.7	74.5	ND	ND	ND	ND
CA322	ND	ND	0.176	0.06	4.5	16.8	ND	7.1	75.2	73.9	66.4	71.8	1.03	ND	ND	0.34
CA332	ND	ND	ND	ND	3.0	14.8	ND	5.9	51.5	53.2	52.4	52.4	ND	ND	ND	ND
CA342	ND	ND	ND	ND	5.5	15.9	ND	7.1	108	129	106	114.3	ND	ND	ND	ND
Ave	0.12	0.12	0.30	0.18	7.6	12.7	3.3	7.9	87.4	88.7	87.8	87.8	101.52	33.2	26.94	53.90
Int Feedlot Wells																
CA352	0.255	0.33	0.172	0.25	9.4	16.5	10.4	12.1	108	126	96	110	2.94	2.31	1.1	2.12
CA362	NS	NS	5.91	5.91	NS	NS	ND	ND	NS	NS	108	108	NS	NS	14	14
CA382	NS	NS	ND	ND	NS	NS	8.8	8.8	NS	NS	106	106	NS	NS	1.4	1.4
Ave	0.3	0.3	2.0	2.1	9.4	16.5	6.4	7.0	108	126	103	108	2.94	2.31	5.5	5.84

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	TKN (mg/L)				DOC (mg/L)				CO ₂ (mg/L)				Methane (ug/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Deep Wells																
NW122	0.030	ND	0.298	0.11	8.1	7.0	11.3	8.8	80.1	80.1	83.3	81.2	1.45	ND	1.3	0.92
CA213	ND	ND	0.557	0.19	3.9	9.9	ND	4.6	65.1	69.1	68.6	67.6	2.45	2.98	ND	1.81
CA253	ND	ND	0.635	0.21	6.8	10.5	ND	5.8	78.3	80.5	77.0	78.6	1.61	ND	0.91	0.84
CA273	0.08	1.00	0.322	0.47	5.3	12.4	8.1	8.6	87.1	88.9	83.2	86.4	1.22	0.651	ND	0.62
CA313	0.08	ND	0.694	0.26	7.4	17.1	ND	8.2	104	89.8	89.3	94.4	ND	ND	0.54	0.18
CA343	0.11	ND	ND	0.04	8.0	16.6	ND	8.2	113	136	118	122.3	ND	ND	0.95	0.32
Ave	0.05	0.17	0.42	0.21	6.6	12.3	3.2	7.4	87.9	90.7	86.6	88.4	1.12	0.61	0.62	0.78

Notes:

DO - Dissolved Oxygen

TKN - Total Kjeldahl Nitrogen

NO₂+NO₃ - Nitrate plus NitriteCO₂ - Carbon Dioxide

DOC - Dissolved Organic Carbon

NS - Not Sampled

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Alkalinity (mg/L)				Fe ²⁺ (mg/L)				Sulfate (mg/L)				Sulfide (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells																
NW010	124	120	101	115	0.01	0.14	0.04	0.06	25.2	27.3	19.8	24.1	0.36	ND	ND	0.12
NW020	291	282	290	288	ND	0.07	0.05	0.04	45.6	46.1	43.4	45.0	ND	ND	ND	ND
NW030	115	162	154	144	0.15	0.10	0.09	0.11	42.6	32.4	31.3	35.4	ND	ND	ND	ND
NW040	32.1	35	40.3	36	0.12	0.15	0.06	0.11	15.9	27	37.4	26.8	ND	ND	ND	ND
NW050	137	142	162	147	ND	0.13	ND	0.04	82.8	85.6	98.2	88.9	ND	ND	ND	ND
NW060	39.7	45	45.2	43	0.02	0.23	0.22	0.16	33.3	39.5	28.2	33.7	ND	ND	ND	ND
NW070	100	171	167	146	0.06	0.08	0.10	0.08	3.08	42.2	33.3	26.2	ND	ND	ND	ND
NW080	78.6	96	85.9	87	ND	0.11	0.02	0.04	43.4	47.5	44.3	45.1	ND	ND	ND	ND
NW090	181	163	192	179	0.74	0.56	0.09	0.46	20.1	43.3	54.2	39.2	ND	ND	ND	ND
NW100	41.5	25	25.2	31	0.03	0.04	ND	0.02	57.3	76.1	48.8	60.7	ND	ND	ND	ND
NW120	120	149	152	140	0.04	0.06	0.01	0.04	55.8	67.5	81.4	68.2	ND	ND	ND	ND
NW130	128	142	194	155	0.02	0.10	ND	0.04	37.9	31.6	40.2	36.6	ND	ND	ND	ND
CA210	160	214	231	202	ND	0.12	0.06	0.06	116	107	72.2	98.4	ND	ND	ND	ND
CA220	384	472	208	355	0.10	0.08	0.20	0.13	8.25	18.8	11.8	13.0	ND	ND	ND	ND
CA230	97.4	65	91.0	84	0.12	0.11	0.09	0.11	61.8	41.2	31.6	44.9	ND	ND	ND	ND
CA240	30.2	66	85.9	61	0.14	0.07	ND	0.07	41.6	61.5	72.8	58.6	ND	ND	ND	ND
CA250	125	156	162	148	0.14	0.15	0.05	0.11	38.4	56.4	44.7	46.5	ND	ND	ND	ND
CA260	62.5	101	139	101	0.18	0.14	0.22	0.18	51.8	77.7	74.7	68.1	ND	ND	ND	ND
CA270	178	132	149	153	0.09	0.11	0.05	0.08	40.8	41.1	50.0	44.0	ND	ND	ND	ND
CA280	50.5	51	40.4	47	0.19	0.04	0.03	0.09	11.8	16.2	9.68	12.6	ND	ND	ND	ND
CA290	232	205	156	198	0.07	0.09	ND	0.05	44.4	41.3	38.0	41.2	ND	ND	ND	ND
CA310	434	359	NS	397	0.06	0.13	0.37	0.19	47.9	64.5	NS	56.2	ND	ND	NS	ND
CA330	381	445	365	397	ND	0.07	0.15	0.07	41.5	53.7	44.4	46.5	ND	ND	ND	ND
Ave	153	165	147	159	0.10	0.13	0.08	0.10	42.1	49.8	45.9	46.1	0.02	ND	ND	0.01
Shallow Feedlot Wells																
CA350	383	455	389	409	21.25	22.10	17.80	20.38	96.7	49.9	87.8	78.1	ND	ND	ND	ND
CA360	886	1140	505	844	11.50	22.80	5.50	13.27	9.75	32.5	2.47	14.9	3.76	7.97	6.38	6.04
CA370	628	NS	NS	628	21.75	NS	NS	21.75	34.4	NS	NS	34.4	0.51	NS	NS	0.51
CA380	793	926	416	712	7.50	50.80	11.00	23.10	6.77	9.94	7.62	8.1	ND	8.87	4.03	4.30
CA390	NS	NS	210	210	NS	NS	0.01	0.01	NS	NS	85.3	85.3	NS	NS	ND	ND
Ave	673	840	380	560	15.50	8.58	8.58	15.70	36.9	30.8	45.8	44.2	1.07	5.61	2.60	2.17

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Alkalinity (mg/L)				Fe ²⁺ (mg/L)				Sulfate (mg/L)				Sulfide (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow-Int Wells																
NW011	151	162	156	156	ND	0.10	0.02	0.04	40.8	44.6	33.9	39.8	ND	ND	ND	ND
NW021	225	234	219	226	0.03	0.06	0.03	0.04	46.1	52	48.1	48.7	ND	ND	ND	ND
NW031	278	294	255	276	0.02	0.06	0.09	0.06	48.7	55.3	57.0	53.7	ND	ND	ND	ND
NW041	166	168	169	168	ND	0.10	0.05	0.05	36.8	40	41.2	39.3	ND	ND	ND	ND
NW051	222	232	237	230	ND	0.18	ND	0.06	93.9	116	90.3	100.1	ND	ND	ND	ND
NW061	353	383	374	370	ND	0.17	0.22	0.13	33.1	30.3	20.8	28.1	ND	ND	ND	ND
NW071	136	140	134	137	0.06	0.04	0.25	0.12	31.2	40.8	33.4	35.1	ND	ND	ND	ND
NW081	173	179	172	175	ND	0.11	0.02	0.04	50.7	58.3	53.4	54.1	ND	ND	ND	ND
NW091	265	272	248	262	0.17	0.18	0.05	0.13	34.5	46.3	37.9	39.6	ND	ND	ND	ND
NW101	135	124	116	125	0.02	ND	0.14	0.05	48.9	56.5	47.0	50.8	ND	ND	ND	ND
NW131	83.5	90	139	104	0.05	0.08	ND	0.04	34.2	43.3	38.5	38.7	ND	ND	ND	ND
CA211	187	195	188	191	ND	0.06	0.15	0.07	58.5	69.2	63.7	63.8	ND	ND	ND	ND
CA221	176	184	183	181	0.07	0.11	0.12	0.10	31.8	39.8	32.7	34.8	ND	ND	ND	ND
CA231	85.5	82	73.3	80	0.03	0.05	0.02	0.03	36.3	46	33.0	38.4	ND	ND	ND	ND
CA241	104	93	85.9	94	0.08	0.04	ND	0.04	32.4	39.8	44.0	38.7	ND	ND	ND	ND
CA251	141	156	138	145	ND	0.06	0.11	0.06	33.6	45.6	36.6	38.6	ND	ND	ND	ND
CA261	113	109	98.4	107	ND	0.09	0.02	0.04	40.2	50.7	39.9	43.6	ND	ND	ND	ND
CA271	162	132	111	135	0.11	0.10	0.04	0.08	53.1	51	55.6	53.2	ND	ND	ND	ND
CA281	118	109	90.9	106	0.01	0.07	0.03	0.04	40.9	48	41.9	43.6	ND	ND	ND	ND
CA291	87.9	110	93.4	97	0.07	0.04	ND	0.04	39.0	46.1	37.8	41.0	ND	ND	ND	ND
CA311	288	269	264	274	0.02	0.03	0.11	0.05	57.0	57.6	57.8	57.5	ND	ND	ND	ND
CA331	172	161	137	157	ND	0.03	0.13	0.05	33.9	30.8	14.7	26.5	ND	ND	ND	ND
Ave	174	176	167	172	0.03	0.08	0.07	0.06	43.4	50.4	43.6	45.8	ND	ND	ND	ND
Shallow-Int Feedlot Wells																
CA351	301	333	267	300	ND	0.16	ND	0.05	38.5	32.5	29.5	33.5	ND	ND	ND	ND
CA361	NS	NS	441	441	NS	NS	12.60	12.60	NS	NS	30.5	3.1	NS	NS	5.12	5.12
CA381	NS	NS	243	243	NS	NS	2.25	2.25	NS	NS	32.3	32.3	NS	NS	ND	ND
Ave	301	333	317	328	ND	0.16	4.95	4.97	38.5	32.5	21.6	23.0	ND	ND	1.71	1.71

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Alkalinity (mg/L)				Fe ²⁺ (mg/L)				Sulfate (mg/L)				Sulfide (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Intermediate Wells																
NW022	233	220	227	227	0.52	0.69	0.76	0.66	37.8	44	41.6	41.1	ND	ND	ND	ND
NW032	257	256	265	259	0.35	0.60	0.63	0.53	56.9	63.6	60.4	60.3	ND	ND	ND	ND
NW052	268	266	278	271	0.87	1.17	1.07	1.04	89.7	123	85.4	99.4	ND	ND	ND	ND
NW062	420	470	366	419	1.27	1.51	1.40	1.39	25.5	21.5	28.6	25.2	0.36	ND	1.26	0.54
NW082	224	226	217	222	0.02	0.07	0.02	0.04	54.2	64.5	53.4	57.4	ND	ND	ND	ND
NW102	114	107	103	108	0.05	0.03	0.01	0.03	38.1	73	33.4	48.2	ND	ND	ND	ND
NW121	427	326	354	369	ND	0.03	ND	0.01	50.4	50.2	40.7	47.1	ND	ND	ND	ND
NW132	122	117	103	114	0.08	ND	0.12	0.07	36.7	43.5	41.3	40.5	ND	ND	ND	ND
CA212	238	222	206	222	ND	0.03	0.10	0.04	64.6	62	56.4	61.0	ND	ND	ND	ND
CA222	214	221	211	215	0.22	0.24	0.90	0.45	49.7	53.7	46.6	50.0	ND	ND	ND	ND
CA232	114	117	116	116	0.03	0.06	0.05	0.05	30.0	37.3	36.2	34.5	ND	ND	ND	ND
CA242	186	183	179	183	0.03	0.01	ND	0.01	35.2	35.9	37.9	36.3	ND	ND	ND	ND
CA252	212	218	207	212	ND	0.06	0.03	0.03	43.2	54.7	48.4	48.8	ND	ND	ND	ND
CA262	218	231	215	221	0.05	0.15	ND	0.07	54.0	61.7	56.9	57.5	ND	ND	ND	ND
CA272	171	169	172	171	ND	0.65	0.05	0.23	48.6	53.3	51.7	51.2	0.23	ND	ND	0.08
CA282	129	127	121	126	0.10	0.06	0.10	0.09	40.2	47.3	41.7	43.1	ND	ND	ND	ND
CA292	144	148	149	147	0.02	0.09	ND	0.04	34.2	36.5	40.5	37.1	ND	ND	ND	ND
CA312	155	181	172	169	0.06	0.04	0.15	0.08	35.9	37.1	40.9	38.0	ND	ND	ND	ND
CA322	171	168	151	163	0.05	0.04	ND	0.03	25.1	33.7	28.4	29.1	ND	ND	ND	ND
CA332	117	121	119	119	0.25	0.01	0.10	0.12	30.5	37.5	37.4	35.1	ND	ND	ND	ND
CA342	246	294	241	260	0.32	0.77	0.07	0.39	50.3	72.6	58.0	60.3	ND	ND	ND	ND
Ave	209	209	199	205	0.20	0.30	0.26	0.26	44.3	52.7	46.0	47.7	0.03	ND	0.06	0.03
Int Feedlot Wells																
CA352	245	287	218	250	0.57	0.90	0.45	0.64	51.1	45	33.8	43.3	ND	ND	ND	ND
CA362	NS	NS	245	245	NS	NS	1.38	1.38	NS	NS	38.2	38.2	NS	NS	ND	ND
CA382	NS	NS	240	240	NS	NS	ND	0.00	NS	NS	27.5	27.5	NS	NS	ND	ND
Ave	245	287	234	245	0.57	0.90	0.61	0.67	51.1	45.0	33.2	36.3	ND	ND	ND	ND

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Alkalinity (mg/L)				Fe ²⁺ (mg/L)				Sulfate (mg/L)				Sulfide (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Deep Wells																
NW122	182	182	189	184	0.89	1.08	0.76	0.91	18.7	22.3	21.0	20.7	ND	ND	ND	ND
CA213	148	157	156	154	0.57	0.56	0.44	0.52	38.9	46.9	48.7	44.8	ND	ND	ND	ND
CA253	178	183	175	179	0.58	0.79	0.87	0.75	26.9	30.6	30.1	29.2	ND	ND	ND	ND
CA273	198	202	189	196	0.72	0.79	0.82	0.78	23.2	28.8	27.1	26.4	0.23	ND	ND	0.08
CA313	237	204	203	215	0.10	0.07	0.29	0.15	11.3	16.7	14.4	14.1	ND	ND	ND	ND
CA343	257	308	269	278	0.23	0.04	ND	0.09	46.3	51.2	49.4	49.0	ND	ND	ND	ND
Ave	200	206	197	201	0.52	0.56	0.53	0.53	27.6	32.8	31.8	30.7	0.04	ND	ND	0.01

Notes:

DO - Dissolved Oxygen

TKN - Total Kjeldahl Nitrogen

NO₂+NO₃ - Nitrate plus NitriteCO₂ - Carbon Dioxide

DOC - Dissolved Organic Carbon

NS - Not Sampled

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	pH				Conductivity (mS/cm)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells								
NW010	6.77	6.81	6.47	6.68	376	332	283	330
NW020	6.75	7.20	6.80	6.92	815	676	734	742
NW030	6.44	6.91	6.69	6.68	494	511	454	486
NW040	5.59	5.99	5.85	5.81	308	241	496	348
NW050	6.01	6.36	6.31	6.23	1870	1430	1392	1564
NW060	6.20	6.49	6.51	6.40	555	359	359	424
NW070	6.87	7.30	6.67	6.95	218	584	481	428
NW080	6.08	6.32	6.26	6.22	802	753	678	744
NW090	5.92	5.99	5.96	5.96	685	600	657	647
NW100	5.95	5.99	5.91	5.95	1033	820	792	882
NW120	6.25	6.64	6.41	6.43	565	660	659	628
NW130	6.51	6.61	6.53	6.55	517	569	548	545
CA210	6.09	6.47	6.37	6.31	1830	1960	1470	1753
CA220	6.85	7.18	6.98	7.00	790	486	447	574
CA230	5.89	5.97	6.08	5.98	547	410	366	441
CA240	6.25	6.43	6.34	6.34	791	663	515	656
CA250	6.63	6.65	6.55	6.61	623	714	687	675
CA260	6.05	6.39	6.27	6.24	533	560	557	550
CA270	6.43	6.14	6.41	6.33	555	363	510	476
CA280	5.99	5.95	6.17	6.04	431	197	219	282
CA290	6.75	6.72	6.39	6.62	837	800	703	780
CA310	6.78	6.66	6.77	6.74	1590	840	819	1083
CA330	6.76	6.86	6.61	6.74	1009	1154	1014	1059
Ave	6.34	6.52	6.40	6.42	773	682	645	700
Shallow Feedlot Wells								
CA350	6.15	6.52	6.29	6.32	1381	1220	1510	1370
CA360	6.73	6.58	7.00	6.77	4050	3370	2900	3440
CA370	6.71	NS	NS	6.71	1433	NS	NS	1433
CA380	6.78	6.56	6.83	6.72	2510	2450	2350	2437
CA390	NS	NS	6.77	6.77	NS	NS	940	940
Ave	6.59	6.55	6.72	6.66	2344	2347	1925	1924

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	pH				Conductivity (mS/cm)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow-Int Wells								
NW011	7.03	7.16	6.86	7.02	434	429	411	425
NW021	6.84	7.07	6.85	6.92	585	623	523	577
NW031	7.39	7.83	7.30	7.51	603	577	593	591
NW041	7.24	7.16	6.92	7.11	477	516	466	486
NW051	6.64	6.73	6.60	6.66	1172	1108	1163	1148
NW061	6.76	6.73	6.64	6.71	885	821	907	871
NW071	6.82	6.54	6.67	6.68	489	426	461	459
NW081	6.35	6.33	6.39	6.36	1021	869	1034	975
NW091	6.61	6.63	6.71	6.65	671	536	595	601
NW101	6.40	6.52	6.36	6.43	864	788	761	804
NW131	6.15	6.02	6.21	6.13	585	504	578	556
CA211	6.68	6.73	6.57	6.66	883	951	934	923
CA221	7.14	7.20	7.01	7.12	468	418	453	446
CA231	6.36	6.18	6.27	6.27	488	429	399	439
CA241	6.47	6.77	6.53	6.59	502	476	484	487
CA251	6.23	6.56	6.41	6.40	751	644	645	680
CA261	6.57	6.16	6.40	6.38	587	483	524	531
CA271	6.40	6.41	6.36	6.39	563	586	548	566
CA281	6.32	6.42	6.22	6.32	618	556	470	548
CA291	6.23	6.78	6.23	6.41	518	580	542	547
CA311	6.99	6.92	6.70	6.87	692	809	803	768
CA331	6.72	6.70	6.53	6.65	639	687	532	619
Ave	6.65	6.71	6.58	6.65	569	628	628	638
Shallow-Int Feedlot Wells								
CA351	6.43	6.61	6.58	6.54	799	759	670	743
CA361	NS	NS	6.86	6.86	NS	NS	2830	2830
CA381	NS	NS	6.75	6.75	NS	NS	651	651
Ave	6.43	6.61	6.73	6.72	799	759	1384	1408

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	pH				Conductivity (mS/cm)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Intermediate Wells								
NW022	7.02	7.48	7.03	7.18	525	501	501	509
NW032	7.45	7.54	7.26	7.42	629	667	603	633
NW052	6.94	7.33	7.01	7.09	784	681	829	765
NW062	6.73	6.94	6.85	6.84	981	986	875	947
NW082	6.89	6.82	6.62	6.78	974	921	1050	982
NW102	6.53	6.65	6.49	6.56	703	561	566	610
NW121	7.08	7.21	6.80	7.03	845	870	903	873
NW132	6.27	6.49	6.21	6.32	681	673	677	677
CA212	6.83	7.17	6.96	6.99	812	639	616	689
CA222	7.22	7.40	7.40	7.34	581	517	510	536
CA232	6.66	6.80	6.62	6.69	380	364	370	371
CA242	7.17	7.28	7.06	7.17	475	457	444	459
CA252	6.65	6.74	6.58	6.66	886	848	834	856
CA262	7.03	7.04	6.96	7.00	635	695	619	650
CA272	6.64	6.64	6.72	6.67	580	549	603	577
CA282	6.57	6.94	6.52	6.68	559	448	491	499
CA292	6.59	6.76	6.48	6.61	502	526	531	520
CA312	6.84	6.60	6.67	6.69	556	558	606	573
CA322	6.58	6.75	6.53	6.62	549	642	599	597
CA332	6.87	6.72	6.58	6.72	332	497	432	420
CA342	6.70	6.80	6.74	6.75	482	775	719	659
Ave	6.82	6.96	6.76	6.85	641	637	637	638
Int Feedlot Wells								
CA352	6.89	7.14	7.03	7.02	607	566	502	558
CA362	NS	NS	7.37	7.37	NS	NS	553	553
CA382	NS	NS	7.40	7.40	NS	NS	453	453
Ave	6.89	7.14	7.27	7.26	607	566	503	521

TABLE 6-1

**SUMMARY OF OFF-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	pH				Conductivity (mS/cm)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Deep Wells								
NW122	7.06	7.28	7.03	7.12	424	453	392	423
CA213	7.43	7.60	7.31	7.45	423	413	409	415
CA253	7.18	7.17	7.05	7.13	431	389	396	405
CA273	7.30	7.25	7.25	7.27	441	446	444	444
CA313	7.21	7.25	7.11	7.19	379	397	388	388
CA343	6.95	6.97	6.88	6.93	738	810	674	741
Ave	7.19	7.25	7.11	7.18	473	485	451	469

Notes:

DO - Dissolved Oxygen

TKN - Total Kjeldahl Nitrogen

NO₂+NO₃ - Nitrate plus Nitrite

CO₂ - Carbon Dioxide

DOC - Dissolved Organic Carbon

NS - Not Sampled

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Redox (mV)				DO (mg/L)				NO ₃ +NO ₂ (mg/L)				Ammonia (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells																
G0011	-66	-63	-70	-66	2.13	0.42	0.31	0.95	ND	ND	ND	ND	0.140	0.179	0.198	0.17
G0012	-20	-53	-28	-34	1.73	0.31	0.26	0.78	ND	ND	ND	ND	ND	ND	ND	ND
G0013	-62	-79	-61	-67	1.79	0.23	0.27	0.76	ND	ND	ND	ND	0.363	0.369	0.473	0.40
G0014	-16	-50	-22	-29	1.19	0.99	0.41	0.86	ND	ND	ND	ND	0.199	0.115	0.223	0.18
G0015	-24	-50	-41	-38	1.52	0.90	0.65	1.02	ND	ND	ND	ND	0.129	ND	ND	0.04
G0016	118	120	110	116	2.09	2.81	2.56	2.49	2.08	1.66	ND	1.25	ND	ND	ND	ND
G0017	71	101	80	84	4.51	3.50	2.31	3.44	2.54	1.37	1.12	1.68	ND	ND	ND	ND
G0018	164	74	130	123	1.31	1.94	1.19	1.48	2.55	2.32	2.52	2.46	0.09	ND	ND	0.03
G0019	106	106	93	102	4.39	4.72	2.52	3.88	0.89	ND	ND	0.30	ND	ND	ND	ND
G0020	129	26	11	55	3.23	3.54	2.33	3.03	0.76	ND	ND	0.25	ND	ND	0.086	0.03
G0021	117	102	143	121	0.85	1.89	1.90	1.55	0.85	ND	ND	0.28	0.796	ND	1.19	0.66
G0022	166	95	111	124	4.03	5.37	4.89	4.76	3.29	3.85	3.80	3.65	ND	ND	ND	ND
G0023	147	123	127	132	2.01	3.99	1.39	2.46	2.47	3.58	3.94	3.33	0.738	ND	1.42	0.72
G0024	145	105	135	128	1.14	0.76	0.59	0.83	19.2	16.4	10.2	15.3	ND	ND	ND	ND
G0025	155	169	125	150	3.45	3.89	2.82	3.39	4.19	3.63	3.95	3.92	ND	ND	ND	ND
G0029	124	91	137	117	1.49	0.30	0.29	0.69	3.92	ND	7.05	3.66	ND	ND	ND	ND
G0030	134	145	135	138	1.15	0.42	0.27	0.61	3.28	4.76	2.00	3.35	0.176	0.176	0.146	0.17
G0031	158	190	118	155	1.12	0.99	1.11	1.07	6.68	7.93	9.59	8.07	ND	ND	ND	ND
G0032	188	181	111	160	0.23	0.56	0.29	0.36	14	13.5	15.2	14.2	ND	ND	ND	ND
G0033	90	195	123	136	4.32	7.00	8.37	6.56	38.2	34.1	37.8	36.7	ND	ND	ND	ND
G0042	125	107	104	112	3.90	4.89	4.40	4.40	1.15	1.08	2.69	1.64	ND	ND	ND	ND
G0043	137	120	103	120	8.58	7.00	4.92	6.83	2.28	2.55	1.61	2.15	ND	ND	ND	ND
G0044	95	190	94	126	6.76	1.17	4.59	4.17	1.80	2.63	2.53	2.32	ND	ND	ND	ND
G0046	124	102	91	106	3.52	5.01	3.73	4.09	1.79	1.76	1.47	1.67	ND	ND	ND	ND
G0047	131	105	116	117	1.08	2.18	2.00	1.75	ND	ND	ND	ND	ND	ND	ND	ND
G0048	155	134	134	141	6.11	7.72	5.67	6.50	1.02	5.51	30.5	12.34	ND	0.256	ND	0.09
G0052	156	184	142	161	0.98	0.39	0.38	0.58	7.66	7.68	9.38	8.24	2.57	2.94	1.00	2.17
G0063	NS	65	65	65	NS	0.50	0.36	0.43	NS	ND	ND	ND	NS	ND	0.361	0.18
G0066	138	123	114	125	0.57	1.42	1.37	1.12	13.1	10.8	8.84	10.91	4.39	3.28	3.84	3.84
G0067	168	146	153	156	0.97	2.45	2.70	2.04	1.16	4.23	6.15	3.85	0.05	ND	ND	0.02
G0068	103	85	76	88	2.62	1.50	1.90	2.01	ND	ND	ND	ND	ND	ND	ND	ND
G0079	NS	NS	51	51	NS	NS	1.71	1.71	NS	NS	4.54	4.54	NS	NS	ND	ND

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Redox (mV)				DO (mg/L)				NO ₃ +NO ₂ (mg/L)				Ammonia (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
PZ001	NM	-45	-1	-23	NM	2.02	2.81	2.42	NM	ND	1.01	0.51	NM	ND	ND	ND
PZ004	NM	-70	-8	-54	NM	1.20	0.81	1.01	NM	ND	ND	ND	NM	ND	0.113	0.06
PZ005	NM	25	16	21	NM	3.32	2.41	2.87	NM	1.23	0.838	1.03	NM	ND	ND	ND
PZ006	NM	35	20	28	NM	0.43	0.91	0.67	NM	1.23	ND	0.62	NM	0.201	0.181	0.19
PZ007	NM	26	-23	2	NM	5.49	3.26	4.38	NM	1.01	ND	0.51	NM	ND	ND	ND
PZ008	NM	4	-34	-15	NM	4.43	3.02	3.73	NM	ND	ND	ND	NM	ND	ND	ND
PZ009	NM	97	80	89	NM	2.00	1.83	1.92	NM	ND	1.05	0.53	NM	ND	ND	ND
PZ010	NM	96	82	89	NM	1.01	0.76	0.89	NM	1.5	ND	0.75	NM	0.284	0.116	0.20
PZ011	NM	100	109	105	NM	0.23	0.25	0.24	NM	3.34	1.30	2.32	NM	8.05	9.31	8.68
PZ012	NM	98	90	94	NM	0.62	0.75	0.69	NM	5.44	1.89	3.67	NM	3.50	10.30	6.90
PZ013	NM	99	78	89	NM	0.14	0.36	0.25	NM	9.45	4.60	7.03	NM	16.5	13.6	15.1
PZ014	NM	-49	42	-4	NM	1.50	0.60	1.05	NM	ND	ND	ND	NM	ND	0.119	0.06
PZ015	NM	163	144	154	NM	7.59	5.92	6.76	NM	3.87	2.05	2.96	NM	ND	ND	ND
PZ016	NM	149	136	143	NM	7.70	5.48	6.59	NM	2.88	2.89	2.89	NM	ND	ND	ND
Ave.	105	80	74	80	2.63	2.59	2.12	2.39	4.50	3.54	3.92	3.67	0.32	0.80	0.93	0.87
Shallow-Int Wells																
G0026	54	34	116	68	1.93	0.32	0.29	0.85	5.37	1.7	1.66	2.91	ND	ND	ND	ND
G0027	-90	-107	-85	-94	1.75	0.49	0.32	0.85	ND	ND	ND	ND	0.914	0.831	0.507	0.75
G0028	-82	-80	-79	-80	1.53	0.82	0.23	0.86	ND	ND	ND	ND	ND	ND	0.140	0.05
G0075	12	53	37	34	0.53	1.10	1.54	1.06	1.91	4.36	4.26	3.51	ND	ND	ND	ND
G0077	111	71	85	89	0.74	0.12	0.24	0.37	10.1	4.8	8.27	7.72	0.738	1.55	0.272	0.85
Ave.	1	-6	15	3	1.30	0.57	0.52	0.80	3.48	2.17	2.84	2.83	0.33	0.48	0.18	0.33
Intermediate Wells																
G0045	118	39	49	69	1.33	0.12	0.56	0.67	ND	ND	ND	ND	2.67	1.4	0.561	1.54
G0049	181	107	107	132	0.35	0.25	0.35	0.32	0.091	ND	ND	0.03	1.76	3.52	1.64	2.31
G0076	-84	-74	-76	-78	0.66	0.12	0.20	0.33	ND	ND	ND	ND	0.976	1.33	1.69	1.33
G0078	60	20	43	41	0.57	0.20	0.55	0.44	ND	ND	ND	ND	ND	ND	ND	ND
Ave.	69	23	31	41	0.73	0.17	0.42	0.44	0.02	ND	ND	0.01	1.35	1.56	0.97	1.30
Deep Wells																
G0070	-56	-89	-82	-76	0.59	0.16	0.35	0.37	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

DO - Dissolved Oxygen; TKN - Total Kjeldahl Nitrogen; NO₂+NO₃ - Nitrate plus Nitrite
CO₂ - Carbon Dioxide; DOC - Dissolved Organic Carbon; NS - Not Sampled; NM - Not measured

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	TKN (mg/L)				DOC (mg/L)				CO ₂ (mg/L)				Methane (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells																
G0011	0.103	0.506	0.542	0.38	17.8	12.8	ND	10.2	177	183	179	180	3.44	4.09	ND	2.51
G0012	ND	0.364	0.347	0.24	12.2	51.2	ND	21.1	186	194	181	187	4.94	8.91	3.5	5.78
G0013	0.221	0.703	1.00	0.64	16.1	6.8	ND	7.6	165	188	180	178	4.06	6.71	5.1	5.29
G0014	0.169	0.461	0.347	0.33	12.0	7.0	13.0	10.7	190	192	172	185	21.7	59.8	10	30.50
G0015	ND	0.315	0.385	0.23	14.9	8.8	6.4	10.0	186	201	200	196	1.55	ND	ND	0.52
G0016	0.221	0.433	0.358	0.34	10.9	13.1	18.4	14.1	169	172	172	171	ND	ND	ND	ND
G0017	0.198	0.521	0.309	0.34	8.3	14.3	11.1	11.2	175	209	158	181	ND	ND	ND	ND
G0018	0.040	0.212	0.268	0.17	5.2	8.5	ND	4.6	127	132	154	138	ND	ND	ND	ND
G0019	ND	0.257	0.266	0.16	9.4	9.1	6.3	8.3	162	180	157	166	ND	ND	ND	ND
G0020	ND	0.257	0.121	0.13	10.7	7.6	ND	6.1	124	147	128	133	1.35	ND	ND	0.45
G0021	0.485	1.72	1.33	1.18	8.2	13.6	ND	7.3	126	127	118	124	28.2	ND	ND	9.40
G0022	ND	0.106	ND	0.04	22.1	5.6	ND	9.2	84.9	98.6	94.6	93	ND	ND	ND	ND
G0023	0.165	0.519	1.49	0.72	6.3	16.6	9.9	10.9	59.9	114	90.6	88	1.53	ND	ND	0.51
G0024	ND	0.088	ND	0.03	11.5	5.8	12.8	10.0	74.4	95.9	63.4	78	ND	ND	ND	ND
G0025	ND	ND	0.119	0.04	10.7	ND	ND	3.6	47.1	46.6	42.2	45	ND	ND	ND	ND
G0029	ND	0.434	0.125	0.19	12.4	12.0	7.0	10.5	87.1	69.1	67.8	75	ND	ND	ND	ND
G0030	0.302	0.417	0.564	0.43	13.3	11.4	5.0	9.9	70.8	86.7	94.4	84	ND	ND	ND	ND
G0031	ND	ND	0.136	0.05	7.9	12.3	19.7	13.3	72.2	81.4	80.0	78	ND	ND	ND	ND
G0032	ND	ND	ND	ND	6.8	15.4	6.1	9.4	154	154	163	157	ND	ND	ND	ND
G0033	ND	ND	0.128	0.04	9.6	12.2	ND	7.3	77	80.5	81.8	80	ND	ND	ND	ND
G0042	0.203	0.822	0.717	0.58	17.1	ND	ND	5.7	149	182	198	176	1.7	ND	ND	0.57
G0043	ND	0.37	0.272	0.21	18.4	ND	ND	6.1	169	194	181	181	ND	ND	ND	ND
G0044	ND	0.47	0.98	0.48	17.0	ND	ND	5.7	207	209	222	213	ND	ND	ND	ND
G0046	0.108	0.941	0.455	0.50	15.2	5.2	22.3	14.2	208	257	228	231	ND	ND	ND	ND
G0047	ND	0.376	0.227	0.20	9.6	8.2	5.6	7.8	117	143	118	126	ND	ND	ND	ND
G0048	0.141	0.453	ND	0.20	7.2	15.4	7.2	9.9	114	144	75.7	111	ND	ND	ND	ND
G0052	2.14	2.36	1.07	1.86	10.4	11.2	12.0	11.2	48.4	59	58.9	55	1.51	ND	ND	0.50
G0063	NS	0.69	0.437	0.56	NS	ND	ND	ND	NS	209	199	204	NS	11.1	4	7.55
G0066	1.52	3.39	3.96	2.96	10.2	10.7	16.0	12.3	135	165	132	144	4.02	8.13	3.4	5.18
G0067	0.080	0.167	ND	0.08	6.2	14.4	ND	6.9	31.2	75.7	71.3	59	1.11	ND	ND	0.37
G0068	ND	0.546	0.676	0.41	14.9	ND	20.0	11.6	244	315	249	269	ND	ND	ND	ND
G0079	NS	NS	ND	ND	NS	NS	6.8	6.8	NS	NS	95.9	96	NS	NS	ND	ND

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	TKN (mg/L)				DOC (mg/L)				CO ₂ (mg/L)				Methane (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
PZ001	NM	0.491	0.577	0.53	NM	ND	6.5	3.3	NM	199	219	209	NM	ND	ND	ND
PZ004	NM	0.449	0.668	0.56	NM	ND	9.2	4.6	NM	232	194	213	NM	ND	ND	ND
PZ005	NM	0.451	0.462	0.46	NM	ND	8.0	4.0	NM	183	172	178	NM	ND	ND	ND
PZ006	NM	0.791	0.451	0.62	NM	ND	ND	ND	NM	171	181	176	NM	7.16	ND	3.58
PZ007	NM	0.382	0.385	0.38	NM	5.0	ND	2.5	NM	169	161	165	NM	ND	ND	ND
PZ008	NM	0.822	0.367	0.59	NM	5.9	ND	3.0	NM	178	167	173	NM	ND	ND	ND
PZ009	NM	0.439	0.367	0.40	NM	11.8	5.4	8.6	NM	181	149	165	NM	ND	ND	ND
PZ010	NM	0.634	0.437	0.54	NM	14.2	14.6	14.4	NM	158	172	165	NM	ND	ND	ND
PZ011	NM	9.04	10.3	9.67	NM	13.0	ND	6.5	NM	148	148	148	NM	35.5	ND	17.8
PZ012	NM	9.42	11.60	10.51	NM	15.3	ND	7.7	NM	172	162	167	NM	23.2	ND	11.6
PZ013	NM	16.90	14.50	15.70	NM	11.3	18.7	15.0	NM	179	148	164	NM	ND	6.9	3.45
PZ014	NM	0.283	0.198	0.24	NM	12.3	7.9	10.1	NM	177	158	168	NM	ND	ND	ND
PZ015	NM	0.207	0.160	0.18	NM	13.8	9.0	11.4	NM	51	110	81	NM	ND	ND	ND
PZ016	NM	0.346	ND	0.17	NM	12.2	9.2	10.7	NM	80.5	68.6	75	NM	ND	ND	ND
Ave.	0.20	1.30	1.24	1.18	11.8	9.4	6.4	8.6	131	155	144	146	2.50	3.66	0.72	2.29
Shallow-Int Wells																
G0026	0.32	0.564	0.699	0.53	18.7	11.5	10.0	13.4	185	187	163	178	ND	ND	4.6	1.53
G0027	1.05	1.28	0.965	1.10	18.1	5.6	8.0	10.6	165	186	178	176	2.09	ND	0.65	0.91
G0028	0.273	0.37	0.571	0.40	18.9	ND	6.8	8.6	176	98.1	193	156	1.07	ND	ND	0.36
G0075	ND	0.153	0.928	0.36	10.0	10.0	5.6	8.5	87.6	103	88.0	93	4.03	ND	ND	1.34
G0077	ND	1.64	1.29	0.98	10.8	6.3	ND	5.7	92.4	96.8	94.6	95	ND	0.802	ND	0.27
Ave.	0.33	0.80	0.89	0.67	15.3	6.7	6.1	9.4	141	134	143	140	1.44	0.16	1.05	0.88
Intermediate Wells																
G0045	2.56	1.75	0.871	1.73	12.2	12.0	ND	8.1	176	193	169	179	1.97	ND	ND	0.66
G0049	0.743	3.7	1.73	2.06	3.7	12.5	ND	5.4	85.5	103	99.4	96	1.30	ND	ND	0.43
G0076	1.06	1.4	1.74	1.40	13.1	ND	ND	4.4	96.8	114	100	104	1.21	12.4	ND	4.54
G0078	ND	0.283	0.113	0.13	10.2	ND	ND	3.4	99.0	108	100	102	1.7	0.6	ND	0.75
Ave.	1.09	1.78	1.11	1.33	9.8	6.1	ND	5.3	114.3	129.5	117.1	120	1.54	3.24	ND	1.59
Deep Wells																
G0070	0.10	0.16	0.085	0.11	9.7	ND	8.2	6.0	79.2	91.1	81.8	84.0	1.08	1.20	ND	0.76

Notes:

DO - Dissolved Oxygen; TKN - Total Kjeldahl Nitrogen; NO₂+NO₃ - Nitrate plus Nitrite
CO₂ - Carbon Dioxide; DOC - Dissolved Organic Carbon; NS - Not Sampled; NM - Not measured

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Alkalinity (mg/L)				Fe ²⁺ (mg/L)				Sulfate (mg/L)				Sulfide (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells																
G0011	402	415	407	408	4.10	4.20	2.73	3.68	298	927	908	711	ND	ND	ND	ND
G0012	422	440	412	425	0.37	0.73	0.59	0.56	656	671	896	741	ND	ND	ND	ND
G0013	374	427	409	403	2.70	2.60	2.44	2.58	1020	1270	1260	1183	ND	ND	ND	ND
G0014	432	436	391	420	0.17	0.30	0.18	0.22	277	496	483	419	ND	ND	ND	ND
G0015	423	456	455	445	1.35	0.30	0.46	0.70	610	571	960	714	ND	ND	ND	ND
G0016	384	392	391	389	0.06	0.02	0.03	0.04	298	390	39.9	243	ND	ND	ND	ND
G0017	398	474	358	410	ND	ND	0.02	0.01	329	273	181	261	ND	ND	ND	ND
G0018	289	300	351	313	0.02	0.08	ND	0.03	195	182	328	235	ND	ND	ND	ND
G0019	368	410	356	378	ND	0.10	0.10	0.07	104	114	105	108	ND	ND	ND	ND
G0020	281	333	291	302	0.09	0.24	0.14	0.16	67.6	68.9	73.5	70	ND	ND	ND	ND
G0021	287	288	269	281	ND	0.09	0.06	0.05	58.3	52.8	44.7	52	ND	ND	ND	ND
G0022	193	224	215	211	0.15	ND	0.02	0.06	26.6	34.6	24.3	29	ND	ND	ND	ND
G0023	136	258	206	200	ND	ND	0.05	0.02	28.3	35.8	30.1	31	ND	ND	ND	ND
G0024	169	218	144	177	ND	0.06	ND	0.02	31.1	37.2	22.4	30	ND	ND	ND	ND
G0025	107	106	96	103	ND	0.12	ND	0.04	15.3	15.8	15.7	16	ND	ND	ND	ND
G0029	198	157	154	170	ND	0.06	0.06	0.04	76	65.5	65.4	69	ND	ND	ND	ND
G0030	161	197	215	191	0.03	0.02	0.04	0.03	56.3	72.1	86.7	72	ND	ND	ND	ND
G0031	164	185	182	177	0.04	0.11	ND	0.05	60.4	68.8	65.5	65	ND	ND	ND	ND
G0032	350	350	371	357	ND	0.01	0.06	0.02	693	798	724	738	ND	ND	ND	ND
G0033	175	183	186	181	0.04	0.05	ND	0.03	49	56.8	51.9	53	ND	ND	ND	ND
G0042	339	414	449	401	ND	0.07	ND	0.02	408	617	605	543	ND	ND	ND	ND
G0043	383	442	412	412	0.14	0.16	0.03	0.11	300	365	297	321	ND	ND	ND	ND
G0044	471	475	505	484	0.03	0.18	0.07	0.09	286	380	416	361	ND	ND	ND	ND
G0046	473	585	518	525	0.04	0.21	0.01	0.09	357	501	394	417	ND	ND	ND	ND
G0047	266	325	268	286	0.03	ND	ND	0.01	102	106	112	107	ND	ND	ND	ND
G0048	258	328	172	253	0.13	0.10	ND	0.08	25.5	54.9	57.8	46	ND	ND	ND	ND
G0052	110	134	134	126	0.09	0.26	ND	0.12	49.8	67.8	52.8	57	ND	ND	ND	ND
G0063	NS	475	452	464	NS	ND	ND	ND	NS	922	629	776	ND	ND	ND	ND
G0066	306	375	300	327	ND	0.07	ND	0.02	40.4	37.4	21.8	33	ND	ND	ND	ND
G0067	70.9	172	162	135	0.14	0.01	0.08	0.08	7.62	26.7	25.9	20	ND	ND	ND	ND
G0068	555	715	566	612	ND	0.11	0.09	0.07	262	275	317	285	ND	ND	ND	ND
G0079	NS	NS	218	218	NS	NS	0.13	0.13	NS	NS	31.8	32	NS	NS	ND	ND

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	Alkalinity (mg/L)				Fe ²⁺ (mg/L)				Sulfate (mg/L)				Sulfide (mg/L)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
PZ001	NM	452	497	475	NM	0.45	0.29	0.37	NM	703	626	665	NM	ND	ND	ND
PZ004	NM	528	442	485	NM	0.42	0.59	0.51	NM	766	795	781	NM	ND	ND	ND
PZ005	NM	415	391	403	NM	0.29	0.16	0.23	NM	568	549	559	NM	ND	ND	ND
PZ006	NM	388	412	400	NM	0.22	0.08	0.15	NM	665	534	600	NM	ND	ND	ND
PZ007	NM	384	366	375	NM	0.32	0.36	0.34	NM	288	323	306	NM	ND	ND	ND
PZ008	NM	404	379	392	NM	0.35	ND	0.18	NM	335	229	282	NM	ND	ND	ND
PZ009	NM	411	338	375	NM	0.09	0.04	0.07	NM	108	123	116	NM	ND	ND	ND
PZ010	NM	360	391	376	NM	0.05	0.06	0.06	NM	153	125	139	NM	ND	ND	ND
PZ011	NM	337	336	337	NM	0.10	0.08	0.09	NM	86	100	93	NM	ND	ND	ND
PZ012	NM	391	369	380	NM	0.14	ND	0.07	NM	74	64.8	67	NM	ND	ND	ND
PZ013	NM	407	336	372	NM	0.17	0.06	0.12	NM	140	106	123	NM	ND	ND	ND
PZ014	NM	403	358	381	NM	0.22	0.02	0.12	NM	87.9	93.8	91	NM	ND	ND	ND
PZ015	NM	116	249	183	NM	0.07	0.10	0.09	NM	28.2	27.0	28	NM	ND	ND	ND
PZ016	NM	183	156	170	NM	0.11	0.08	0.10	NM	28.4	22.3	25	NM	ND	ND	ND
Ave.	298	353	327	332	0.32	0.29	0.20	0.25	226	302	290	282	ND	ND	ND	ND
Shallow-Int Well																
G0026	421	424	371	405	0.06	0.12	0.11	0.10	1180	1150	988	1106	ND	ND	ND	ND
G0027	375	423	404	401	1.84	1.09	0.68	1.20	1180	1260	1110	1183	ND	ND	ND	ND
G0028	399	223	439	354	1.06	1.33	0.99	1.13	1140	1090	1110	1113	ND	ND	ND	ND
G0075	199	235	200	211	0.26	0.01	0.03	0.10	36.3	40.7	30.6	36	ND	ND	ND	ND
G0077	210	220	215	215	ND	ND	0.01	0.00	61.8	35.4	31.6	43	ND	ND	ND	ND
Ave.	321	305	326	317	0.64	0.51	0.36	0.51	720	715	654	696	ND	ND	ND	ND
Intermediate Wells																
G0045	399	438	383	407	0.04	0.04	0.08	0.05	686	786	720	731	ND	ND	ND	ND
G0049	194	233	226	218	0.03	ND	0.13	0.05	39.4	36.2	48.3	41	ND	ND	ND	ND
G0076	220	259	228	236	0.47	0.60	0.74	0.60	41.2	45.3	51.0	46	ND	ND	ND	ND
G0078	225	246	228	233	ND	ND	0.04	0.01	39.0	35.7	34.5	36	ND	ND	ND	ND
Ave.	260	294	266	273	0.14	0.16	0.25	0.18	201	226	213	214	ND	ND	ND	ND
Deep Wells																
G0070	180	207	186	191	0.46	0.47	0.54	0.49	17.9	23.9	18.3	20	ND	ND	ND	ND

Notes: DO - Dissolved Oxygen; TKN - Total Kjeldahl Nitrogen; NO₂+NO₃ - Nitrate plus Nitrite
CO₂ - Carbon Dioxide; DOC - Dissolved Organic Carbon; NS - Not Sampled; NM - Not Measured

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	pH				Conductivity (mS/cm)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
Shallow Wells								
G0011	6.75	7.28	7.00	7.01	2450	2260	2210	2307
G0012	6.89	6.97	6.96	6.94	2150	1820	2090	2020
G0013	6.86	6.87	6.89	6.87	2830	2720	2770	2773
G0014	6.92	7.04	7.10	7.02	1740	1970	1630	1780
G0015	7.04	7.14	7.20	7.13	2140	1900	1950	1997
G0016	6.85	7.05	7.11	7.00	1550	1355	1490	1465
G0017	6.88	7.11	7.20	7.06	1550	1273	1081	1301
G0018	6.83	6.88	7.01	6.91	1294	951	1208	1151
G0019	6.98	7.28	7.22	7.16	949	923	842	905
G0020	6.82	7.23	7.19	7.08	727	700	690	706
G0021	7.11	7.41	7.28	7.27	705	602	614	640
G0022	6.80	7.37	7.15	7.11	497	480	465	481
G0023	6.72	6.60	6.95	6.76	488	594	495	526
G0024	6.17	6.85	6.37	6.46	644	594	370	536
G0025	6.40	6.46	6.81	6.56	286	274	247	269
G0029	6.43	7.13	6.56	6.71	645	450	512	536
G0030	6.44	6.96	6.75	6.72	567	615	753	585
G0031	6.58	7.04	6.65	6.76	557	542	553	551
G0032	7.21	7.53	7.05	7.26	2340	2270	2310	2307
G0033	6.53	7.05	6.65	6.74	663	784	750	732
G0042	7.01	7.01	7.05	7.02	1620	1810	1950	1793
G0043	7.11	7.14	7.20	7.15	1436	1395	1279	1370
G0044	7.03	7.04	7.02	7.03	1510	2350	1560	1807
G0046	6.95	7.02	7.17	7.05	1780	1730	1490	1667
G0047	7.11	7.26	7.22	7.20	750	769	717	745
G0048	6.59	6.43	6.83	6.62	543	719	662	641
G0052	6.10	6.57	6.21	6.29	453	460	444	452
G0063	NS	6.93	7.03	6.98	NS	2150	2370	2260
G0066	6.67	6.83	7.06	3.85	820	792	646	753
G0067	6.56	6.32	6.68	6.52	391	412	407	403
G0068	6.91	6.82	6.85	6.86	1760	1820	1458	1679
G0079	NS	NS	6.80	6.80	NS	NS	509	509

TABLE 6-2

**SUMMARY OF ON-POST NATURAL ATTENUATION PARAMETERS CONCENTRATIONS
CORNHUSKER ARMY AMMUNITION PLANT**

Well Number	pH				Conductivity (mS/cm)			
	Jun-98	Mar-99	Mar-00	Ave.	Jun-98	Mar-99	Mar-00	Ave.
PZ001	NM	6.99	7.10	7.05	NM	2050	1940	1995
PZ004	NM	6.93	7.07	7.00	NM	2110	2130	2120
PZ005	NM	7.10	7.10	7.10	NM	1800	1720	1760
PZ006	NM	7.03	7.09	7.06	NM	1800	1700	1750
PZ007	NM	7.06	7.21	7.14	NM	1200	1224	1212
PZ008	NM	7.04	7.21	7.13	NM	1332	1076	1204
PZ009	NM	7.17	7.20	7.19	NM	908	812	860
PZ010	NM	7.14	7.13	7.14	NM	970	902	936
PZ011	NM	7.09	7.09	7.09	NM	811	824	818
PZ012	NM	7.14	7.04	7.09	NM	881	790	836
PZ013	NM	7.12	7.13	7.13	NM	1089	886	988
PZ014	NM	7.35	7.30	7.33	NM	846	824	835
PZ015	NM	5.93	6.74	6.43	NM	303	517	410
PZ016	NM	6.39	6.78	6.59	NM	386	388	387
Ave.	6.78	6.98	6.99	6.94	1195	1199	1132	1169
Shallow-Int Well								
G0026	7.15	7.19	7.25	7.20	3160	2840	2510	2837
G0027	7.25	7.18	7.28	7.24	2970	2770	2720	2820
G0028	7.11	7.15	7.16	7.14	2730	2740	2650	2707
G0075	6.86	7.14	7.01	7.00	522	472	470	488
G0077	6.76	7.21	6.93	6.97	575	489	553	539
Ave.	7.03	7.17	7.13	7.11	1991	1862	1781	1878
Intermediate Wells								
G0045	6.99	7.16	7.21	7.12	2110	2100	2030	2080
G0049	6.95	6.78	7.17	6.97	500	493	523	505
G0076	7.12	7.48	7.27	7.29	550	502	494	515
G0078	7.20	7.59	7.37	7.39	531	489	497	506
Ave.	7.07	7.25	7.26	7.19	923	896	886	902
Deep Wells								
G0070	7.05	7.46	7.26	7.26	415	386	338	380

Notes: DO - Dissolved Oxygen; TKN - Total Kjeldahl Nitrogen; NO₂+NO₃ - Nitrate plus Nitrite
CO₂ - Carbon Dioxide; DOC - Dissolved Organic Carbon; NS - Not Sampled; NM - Not Measured

TABLE 6-3

**SUMMARY OF ESTIMATED DEGRADATION HALF-LIVES
CORNHUSKER ARMY AMMUNITION PLANT**

Plume Areas	Methods	Estimated Half-Lives (years)											
		RDX				TNT				HMX			
		Single Well ¹	Multiple Well ²	Multiple Well ³	Geometric Mean	Single Well ¹	Multiple Well ²	Multiple Well ³	Geometric Mean	Single Well ¹	Multiple Well ²	Multiple Well ³	Geometric Mean
Load Line 1		5.1	6.1	6.0	5.7	5.7	NA+	NA+	5.7	4.5	9.3	8.8	7.2
Feed Lot		7.0	3.8	2.9	4.3	3.7	1.6	2.8	2.5	0.6	NA+	NA+	0.6
Distal Off-Post Plume		2.9	14.8	16.6	8.9	ND	ND	ND	ND	5.1	10.8	9.2	8.0

Notes:

Half-life estimates were calculated using three methods. The results above are tabulated by method according to the following column numbers.

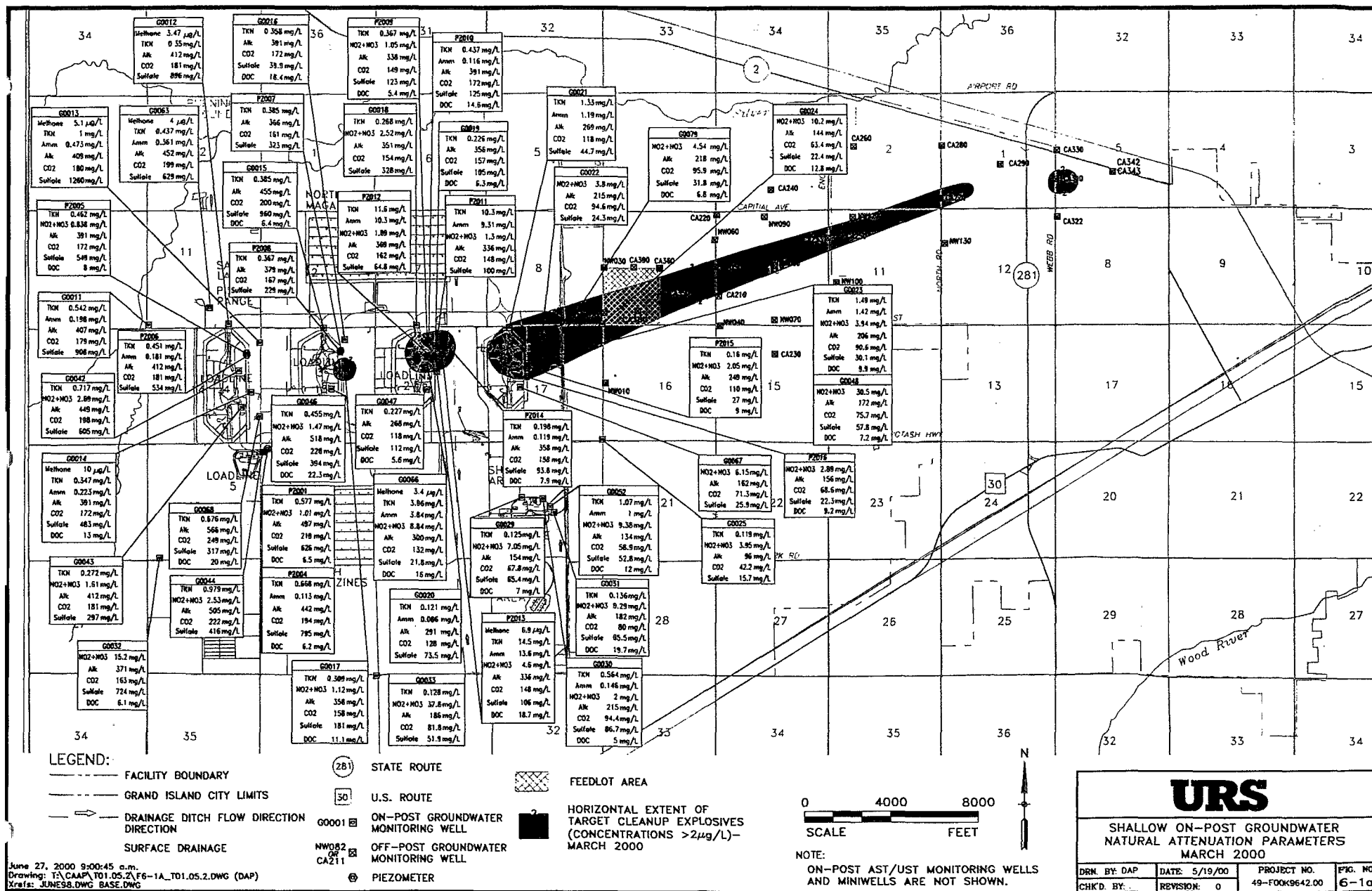
¹ Single well estimate using decreasing concentrations over time using Graves (1995)

² Multiple well estimates using concentrations along the groundwater flow path using Graves (1995)

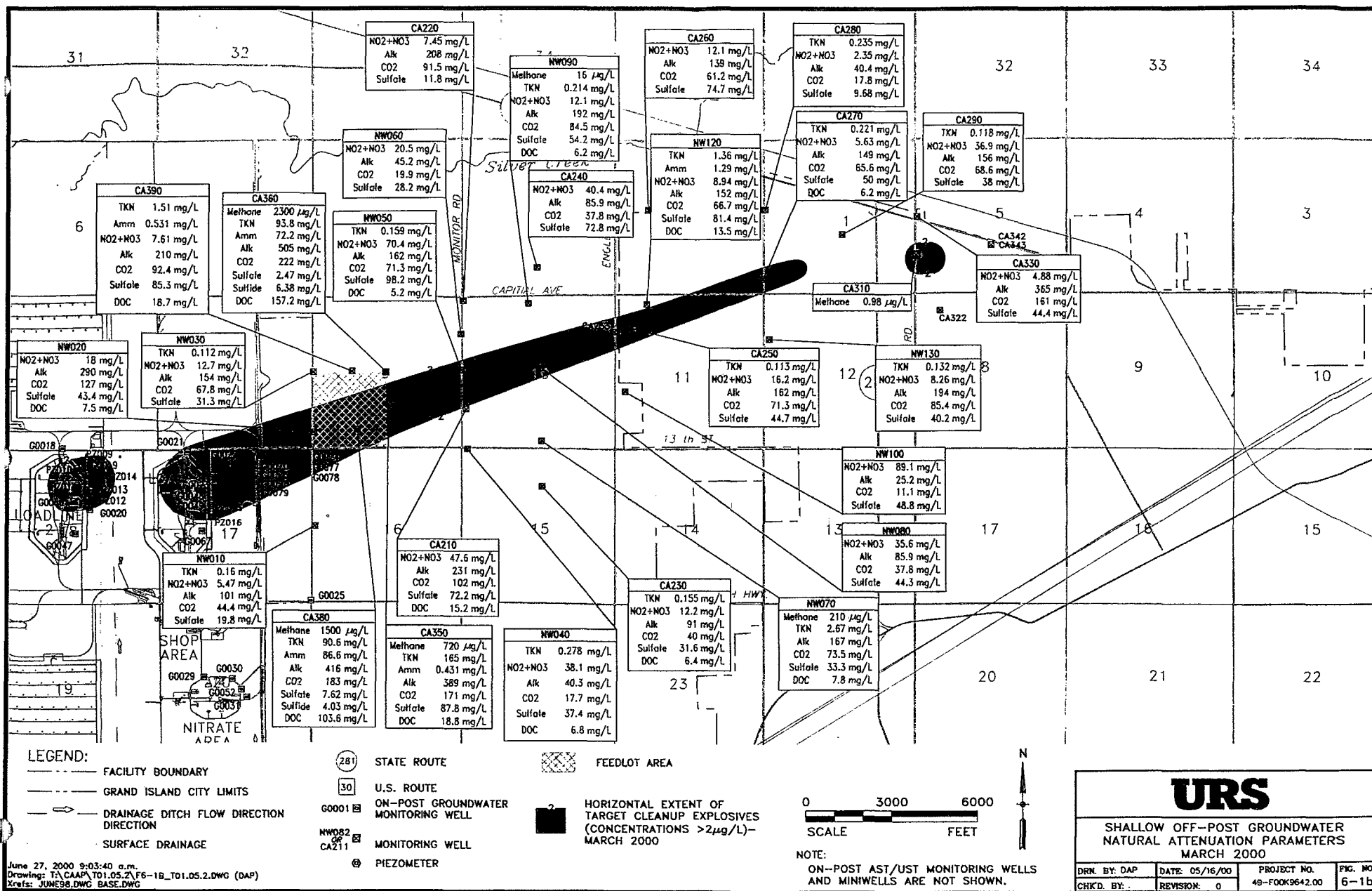
³ Multiple well estimates using concentrations along the groundwater flow path using Buscheck and Alcantar (1995)

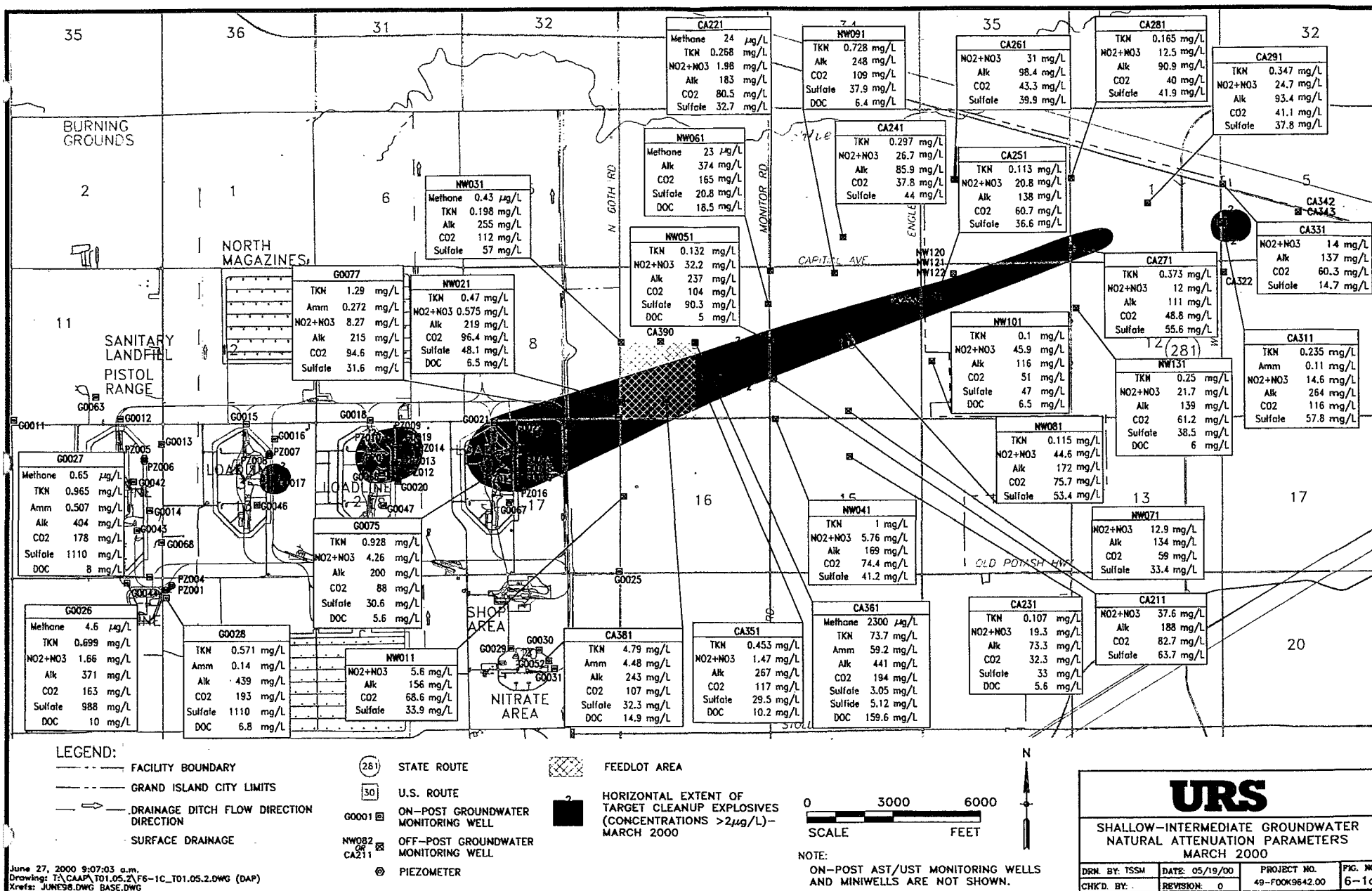
NA+ Not Available. Concentrations increase along flowpath within area.

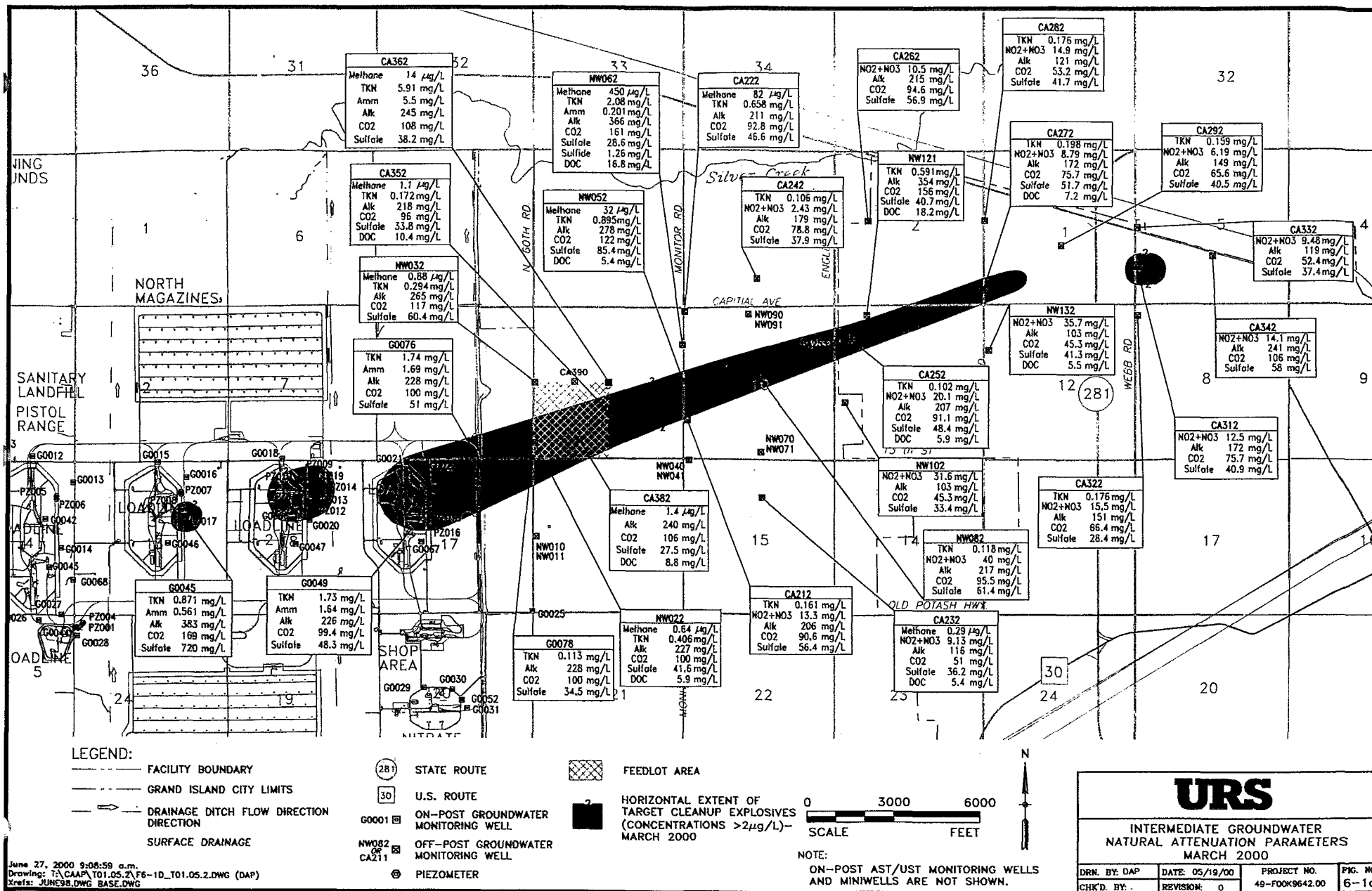
ND Nondetect

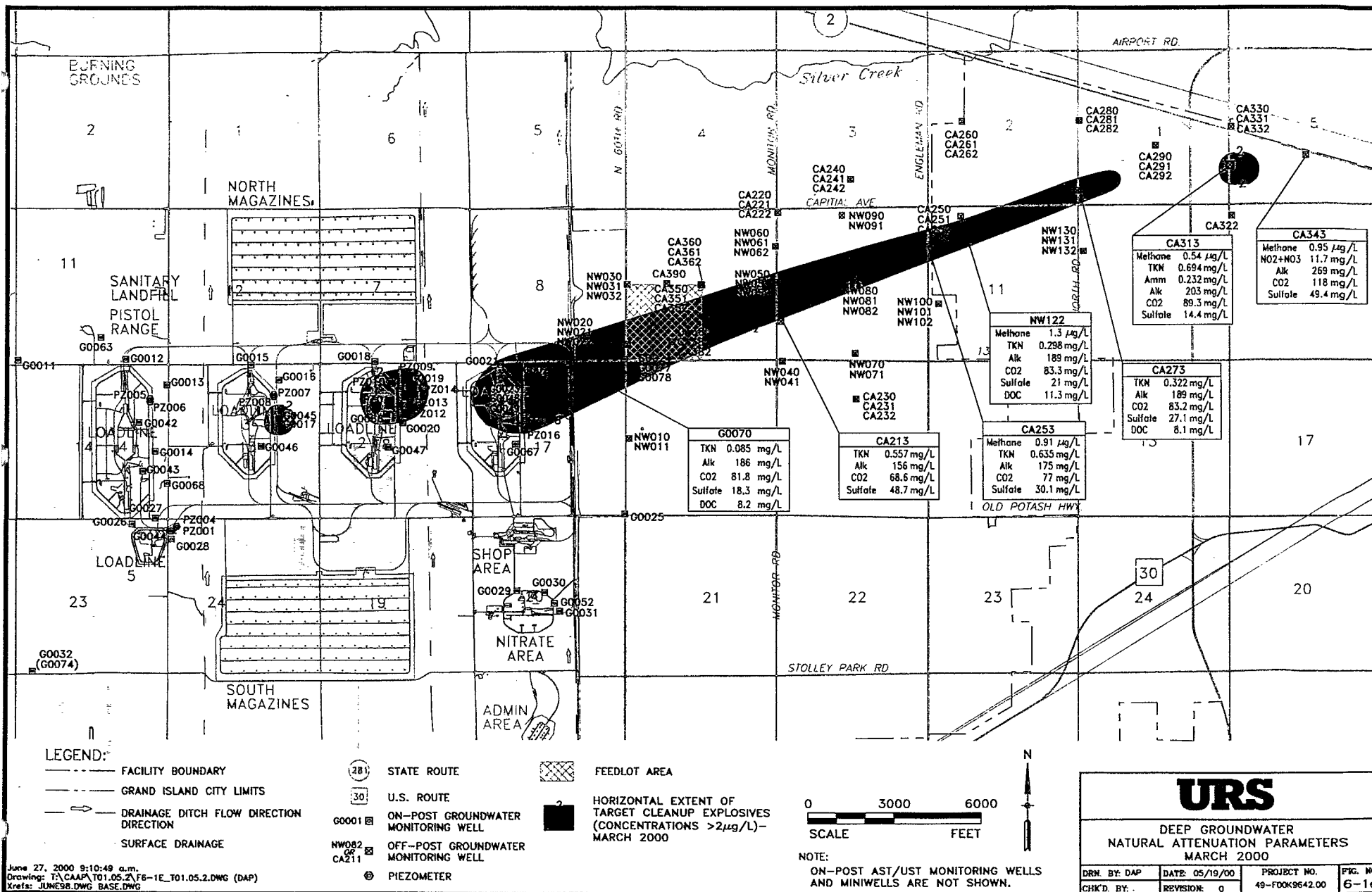


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Xrefs: JUNE98.DWG BASE.DWG



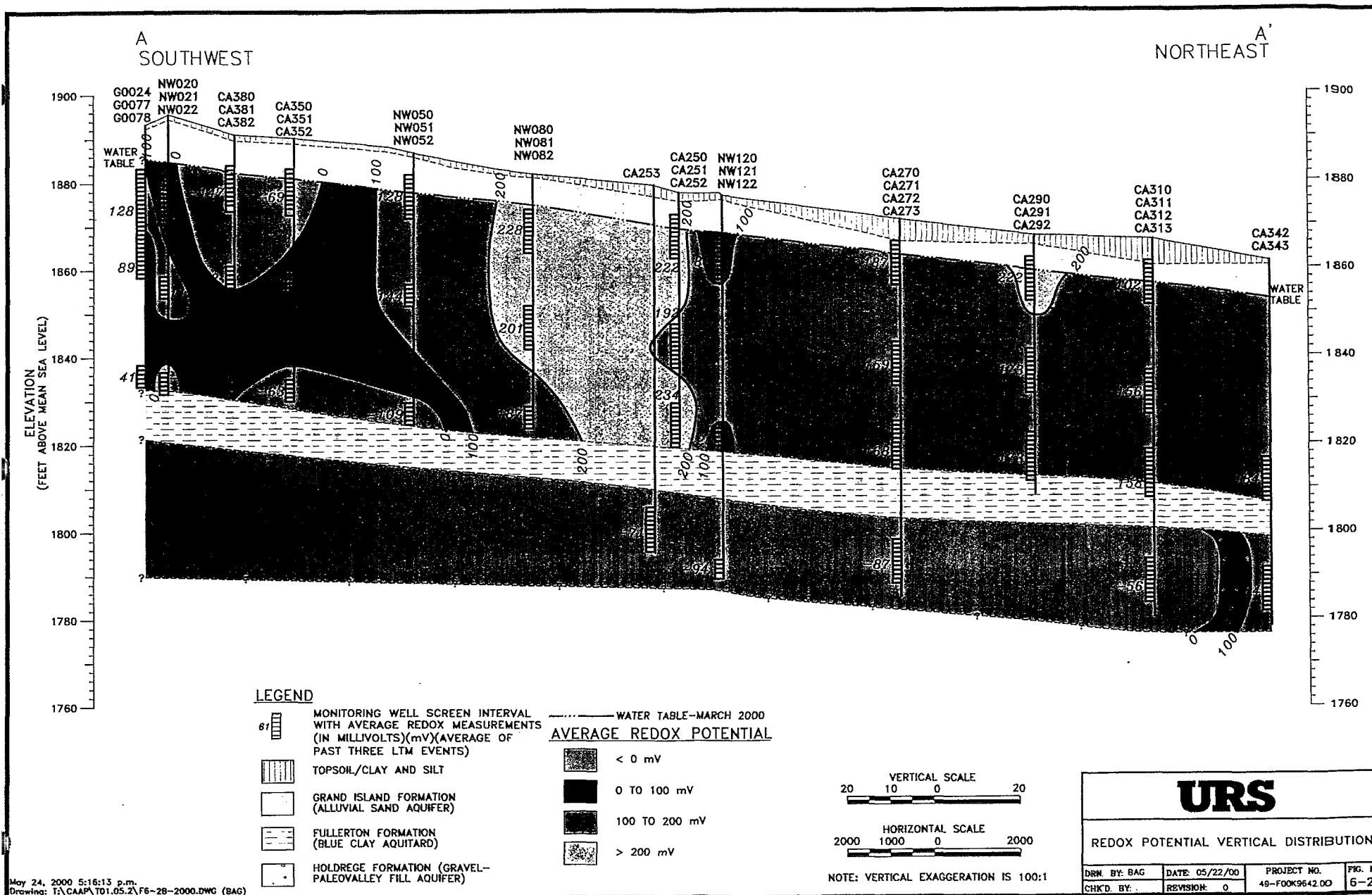


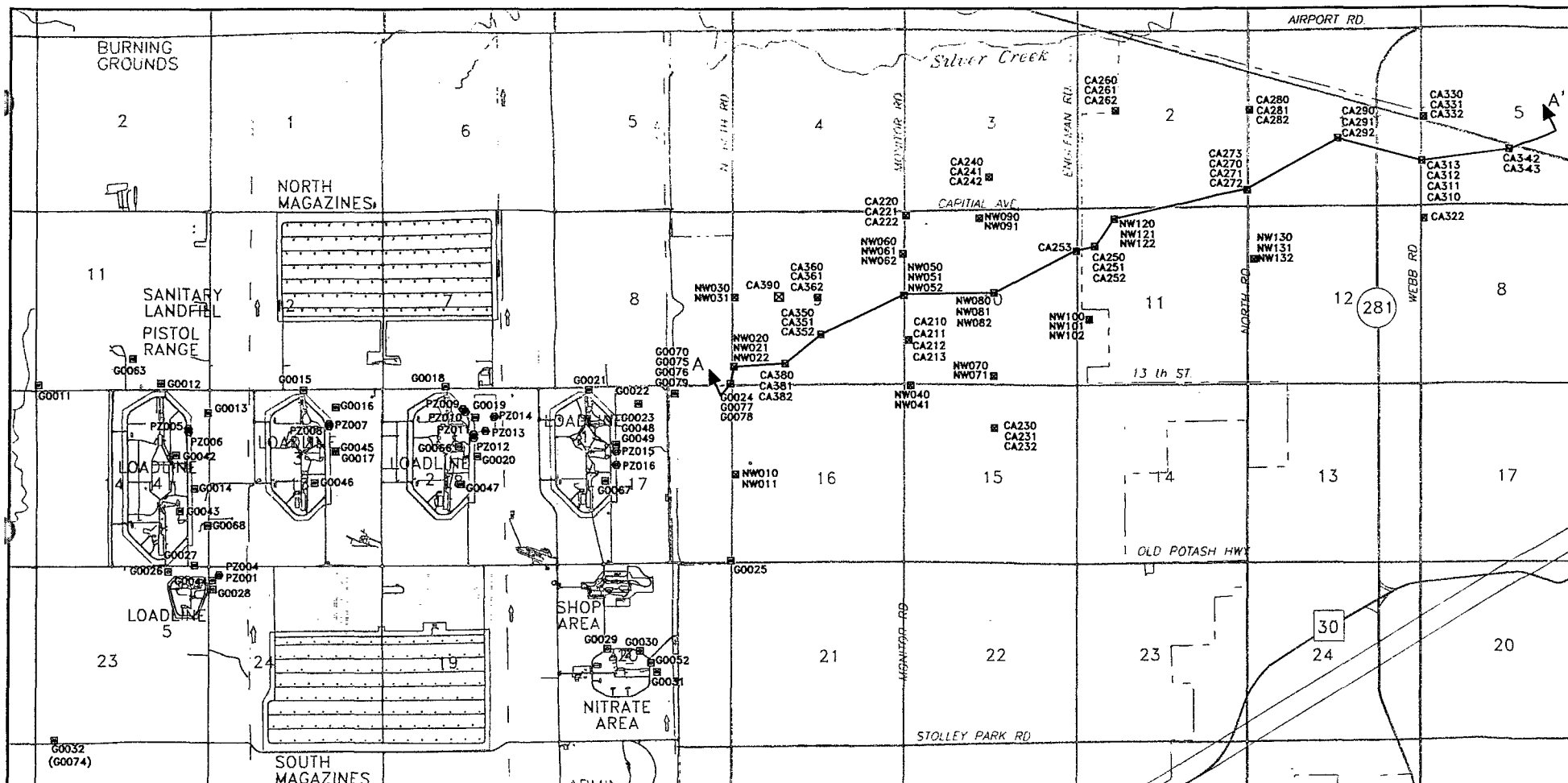




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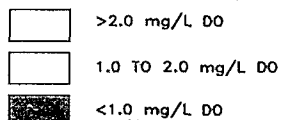
URS			
DEEP GROUNDWATER NATURAL ATTENUATION PARAMETERS MARCH 2000			
DRN. BY: DAP	DATE: 05/19/00	PROJECT NO.	FIG. NO.
CHKD. BY:	REVISION: 0	49-F00K9642.00	6-1e



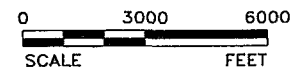
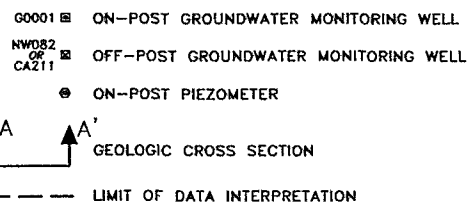


AVERAGE DO CONCENTRATIONS

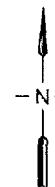
(CONCENTRATIONS ARE AVERAGE VALUES FROM PAST THREE LTM EVENTS)



LEGEND:



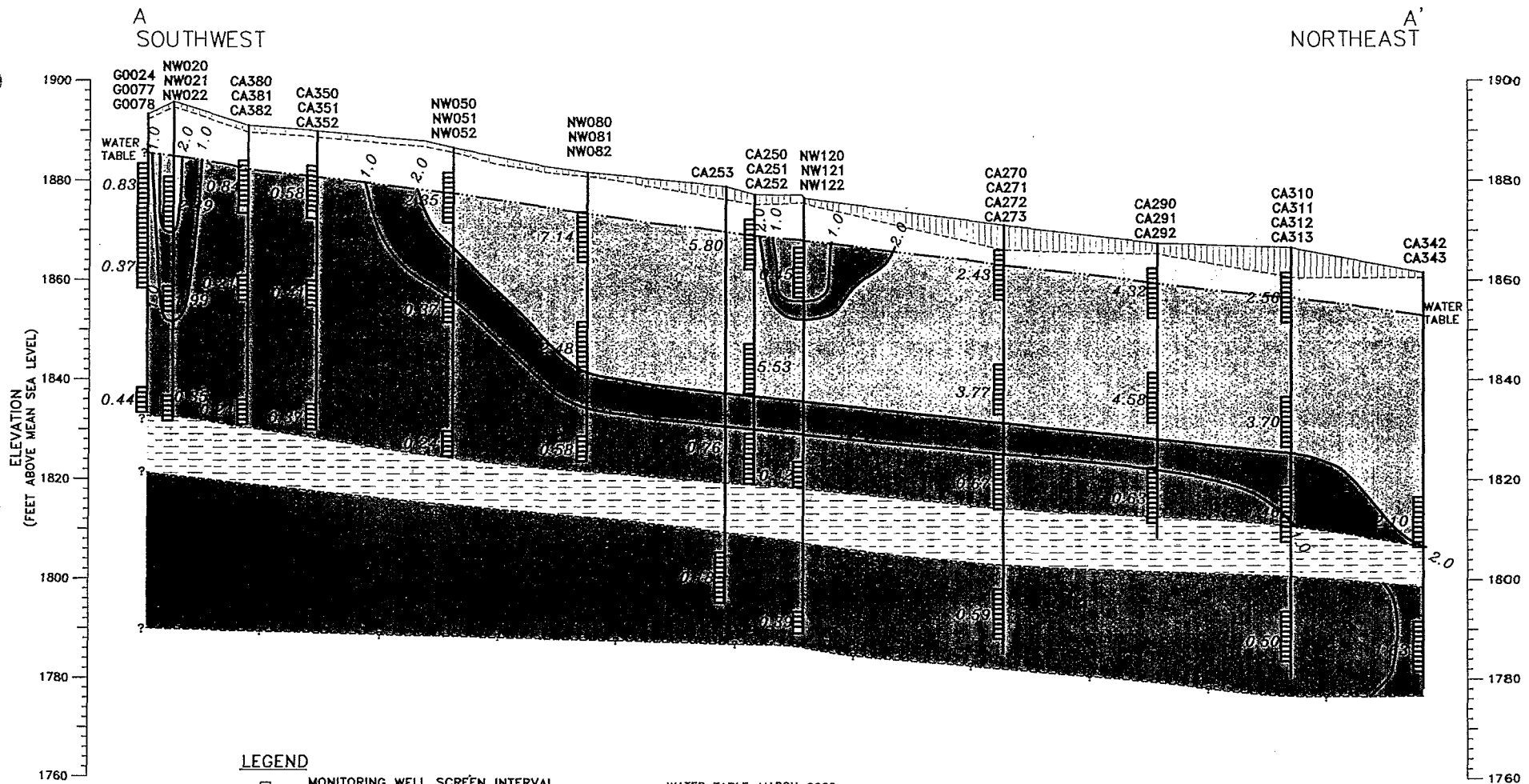
NOTE:
ON-POST AST/UST MONITORING WELLS
AND MINIWELLS ARE NOT SHOWN.



URS

SHALLOW GROUNDWATER DISSOLVED
OXYGEN CONCENTRATIONS

DRN. BY: BAG	DATE: 05/21/00	PROJECT NO.	FIG. NO.
CHK'D. BY:	REVISION: 0	49-F00K9642.00	6-3a

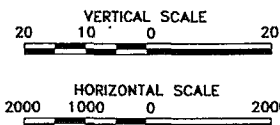


LEGEND

- MONITORING WELL SCREEN INTERVAL WITH AVERAGE DISSOLVED OXYGEN MEASUREMENTS (IN mg/L) (AVERAGE OF PAST THREE LTM EVENTS)
- TOPSOIL/CLAY AND SILT
- GRAND ISLAND FORMATION (ALLUVIAL SAND AQUIFER)
- FULLERTON FORMATION (BLUE CLAY AQUITARD)
- HOLDREGE FORMATION (GRAVEL-PALEOVALLEY FILL AQUIFER)

AVERAGE DO CONCENTRATIONS

- > 2.0 mg/L DO
- 1.0 TO 2.0 mg/L DO
- < 1.0 mg/L DO

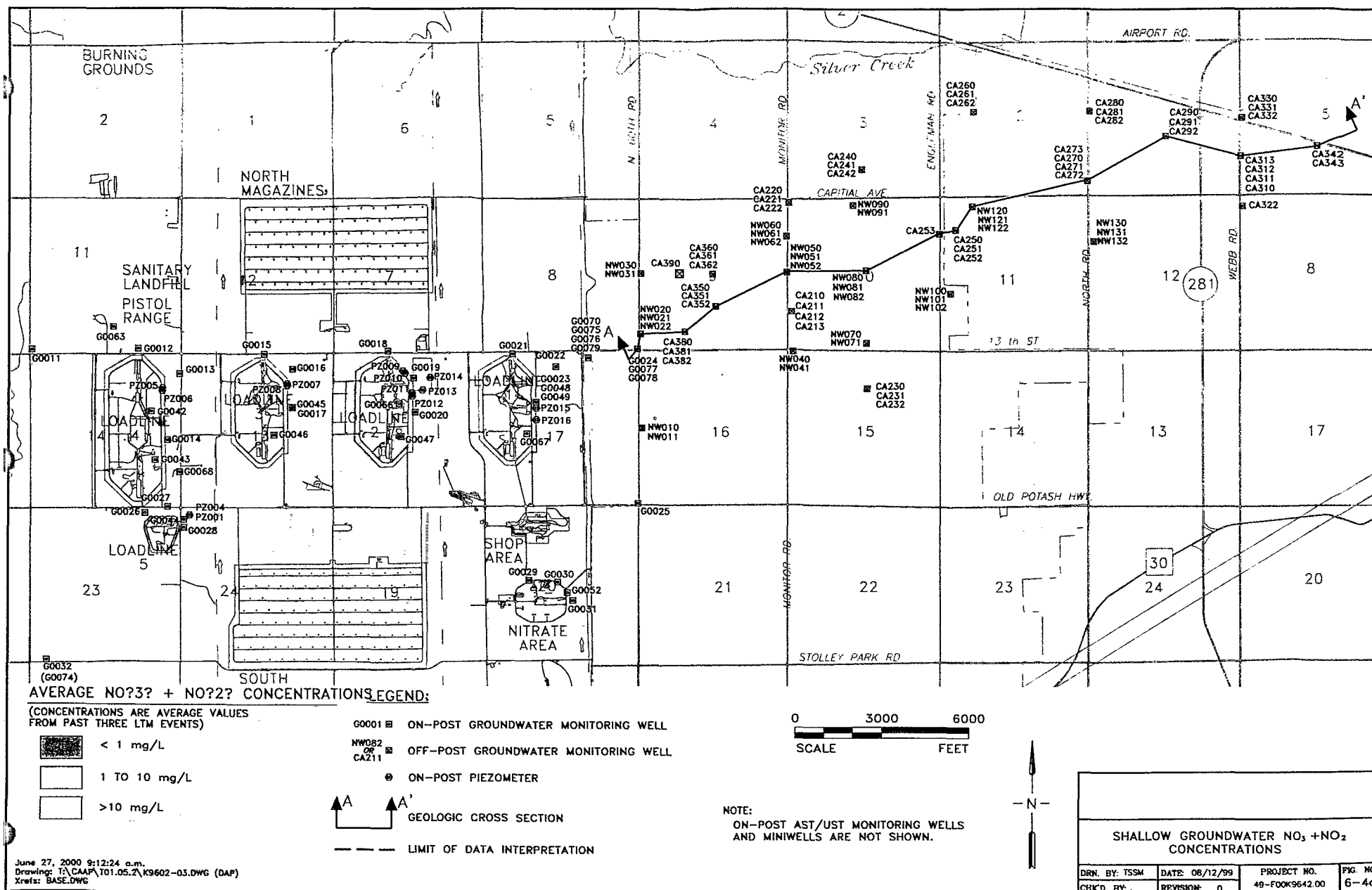


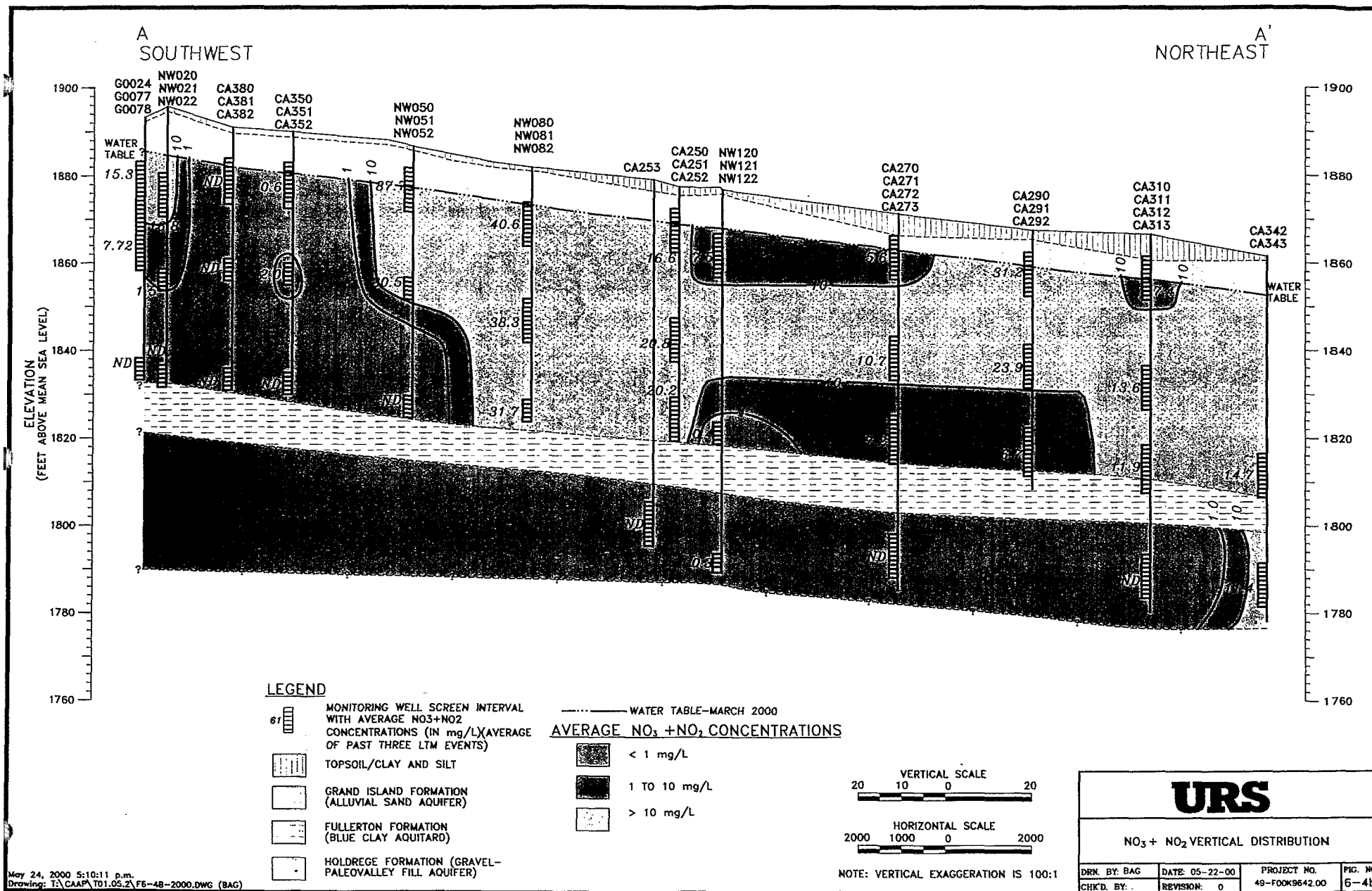
NOTE: VERTICAL EXAGGERATION IS 100:1

URS

DISSOLVED OXYGEN VERTICAL DISTRIBUTION

DRN. BY: BAG	DATE: 05/22/00	PROJECT NO.	FIG. NO.
CHK'D. BY:	REVISION: 0	49-F00K9642.00	6-3b





APPENDIXC Numerical Groundwater Contaminant Fate and Transport Backup

APPENDIXC Numerical Groundwater Contaminant Fate and Transport Backup

As an additional line of evidence in support of natural attenuation of the off-post explosives plume, a numerical groundwater contaminant fate and transport model was developed. The numerical model simulated baseline contaminant transport and transport under remediation conditions. The baseline contaminant fate and transport simulation and the new Proposed Remedy simulation were used to evaluate natural attenuation of the off-post explosives plume.

This appendix includes selected text and figures from the Groundwater Flow and Contaminant Fate and Transport Modeling Final Report (URS 2001). The entire report can be found in the administrative record at the Grand Island Public Library. All section numbers, text, tables, and figures remain unchanged from the original report.

1.1 PURPOSE AND AUTHORITY FOR THE PROJECT

The United States Army Corps of Engineers (USACE) has contracted URS Greiner Woodward Clyde (URSGWC) to complete the long-term monitoring (LTM) program for selected groundwater monitoring wells at the Cornhusker Army Ammunition Plant (CHAAP), located near Grand Island, Nebraska. Work for this assignment is being performed under Contract No. DCAC31-94-D-0059, Delivery Order 0001. The purpose of this report is to present the results of:

- Initial groundwater flow modeling completed by URSGWC, which consisted of recalibration and verification of an existing MODFLOW groundwater flow model.
- Simulation of the on-post groundwater extraction system and evaluation of extraction well capture zones.
- Optimization of the current on-post groundwater extraction system extraction rates and recommendations for a modified on-post groundwater extraction alternative.
- Construction of a three-dimensional numerical solute transport model.
- Simulation of baseline contaminant fate and transport.
- Simulation of contaminant transport under remediation system conditions to evaluate the effectiveness at controlling contaminant transport and at removing contaminant sources.

1.2 SITE HISTORY

CHAAP is located on an 11,936-acre tract approximately 2 miles west of Grand Island, Nebraska. The site also includes an off-post area (to the northeast) consisting of groundwater impacted by explosive compounds that originated at CHAAP.

CHAAP was constructed and became fully operational in 1942 as a U.S. Government-owned, contractor-operated facility. CHAAP was responsible for the production of artillery shells, mines, bombs, and rockets for World War II and the Korean and Vietnam conflicts. The plant was operated intermittently for 30 years with the most recent operations ending in 1973. From 1942-1945, various bombs, shells, boosters and supplementary charges were produced at CHAAP using primarily 2,4,6-trinitrotoluene (TNT). From 1950-1955, artillery shells and rockets were produced using a mixture of TNT, cyclonite (RDX), and cyclotetramethylenetetranitramine (HMX). CHAAP was activated again from 1965-1973 to produce bombs, projectiles, and gravel mini-mines. Explosive wastes and residues associated with munitions loading, assembly, and packing operations have resulted in a groundwater contamination plume that originates at waste leach pits and cesspools of the CHAAP load lines and extends east-northeastward into the city of Grand Island, Nebraska.

The explosive compounds have migrated east-northeast with the predominant direction of groundwater flow. The more mobile compounds, RDX and HMX, have migrated the greatest distances. Highly sorbing compounds such as 2,4,6-TNT have migrated shorter distances. The

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

March 1999 Annual Sampling Event Report (URSGWC 1999b) provides the most comprehensive description of the current nature and extent of groundwater contamination.

Evaluation and remediation of explosives contamination at CHAAP has been an on-going process. The U.S. Army conducted an incineration project (1987-1988) designed to excavate and treat soils beneath unlined leach pits and cesspools of the CHAAP load lines. The purpose of the project was to remove the soil sources of explosives contamination. The project reduced the sources of contamination; however, at many locations remediation action levels could not be achieved before groundwater was encountered. Water quality sampling on- and off-post has been completed repeatedly since the middle 1980s to monitor the extent of groundwater contamination by various contractors under the direction of the United States Army Environmental Center (USAEC).

An on-post groundwater extraction and treatment system was installed in summer 1998 by CET Environmental under the direction of the USACE. Full-time operation began in December 1998. The groundwater extraction system includes six wells with a total extraction flow rate of about 750 gallons per minute. The groundwater is being treated with granular activated carbon and discharged to on-post drainage canals.

The USACE has contracted with URSGWC for six groundwater sampling events for the CHAAP LTM program. The time period for annual sampling is 1996 through 2001. Additional work by URSGWC under this contract included installation of monitoring wells and piezometers, groundwater flow and contaminant fate and transport computer modeling, and an explosives natural attenuation evaluation.

1.3 GROUNDWATER MODELING SCOPE OF WORK

The original objectives for the groundwater flow modeling effort were to recalibrate the MODFLOW (McDonald and Harbaugh 1988) groundwater flow model constructed by Dames and Moore (1995), verify the flow model results based on water level data collected from before and after system startup, and evaluate extraction well capture zones. The scope of work for Modification No. 1 included the additional objectives of optimizing the remediation system pumping rates with the groundwater flow model, and developing a contaminant fate and transport model for the site to evaluate the natural attenuation alternative and remediation system effectiveness.

The overall modeling scope of work to be completed by URSGWC is subsequently presented.

1.3.1 Groundwater Flow Modeling Scope of Work

The groundwater flow modeling scope of work included:

- Recalibration of the original MODFLOW flow model constructed by Dames and Moore (1995) during design of the groundwater pump and treat system for OU1. The flow model was recalibrated to May 1998 pre-pumping water levels. The flow model simulated baseline steady-state groundwater flow conditions for the uppermost aquifer present at the site.

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

- Simulation of the drawdown effects of the on-post groundwater extraction system and verification of the original flow model results based on water level data collected before and after system startup.
- Simulation of advective particle capture zones for the groundwater extraction system using MODPATH (Pollock 1989). Model-predicted capture zones were compared to the explosives plumes to verify capture.
- Evaluation of optimum current and future extraction rates for capture of the plumes.
- Optimization of the groundwater extraction system to meet project remedial objectives.

1.3.2 Contaminant Fate and Transport Modeling Scope of Work

The contaminant fate and transport modeling scope of work included:

- Construction of a three-dimensional, numerical solute transport model using MT3DMS (Zheng 1998). The transport model was used in conjunction with the recalibrated MODFLOW flow model. The transport model retrieved the flow terms from the MODFLOW simulations and calculated chemical concentrations over time. The existing grid and model setup was used as a basis for the fate and transport model. Chemical concentrations were input into the model by discretizing the March 1999 groundwater plume sampling results onto the model grid.
- Evaluation of baseline contaminant fate and transport conditions (i.e., the natural attenuation alternative) for the off-post portion of the plume for two chemicals of concern (e.g., RDX and TNT).
- Evaluation of various remediation alternatives' effectiveness using the two chemicals of concern (e.g., RDX and TNT).

SECTION FOUR

Contaminant Fate and Transport Model

The objective of the numerical contaminant fate and transport modeling effort was to:

- Simulate baseline contaminant transport conditions to evaluate natural attenuation of the off-post plume
- Simulate contaminant transport under various groundwater extraction conditions to evaluate remedial alternatives effectiveness

4.1 MODELING APPROACH, METHODOLOGY, AND ASSUMPTIONS

The approach, methods, and assumptions used to simulate groundwater contaminant fate and transport at CHAAP are discussed in the following sections.

4.1.1 Modeling Approach and Methodology

Groundwater flow conditions at the site were simulated using MODFLOW. The MODFLOW modeling approach and methodology is discussed in **Section 3**. Contaminant fate and transport of explosives was simulated using MT3DMS (Zheng 1998), a three-dimensional block-centered, finite-difference, numerical transport model. MT3DMS retrieves the hydraulic heads, flow terms, and source sink terms from the MODFLOW groundwater flow model results and calculates chemical concentrations over time. The MT3DMS models were constructed using Visual MODFLOW (Guiger 1995). Visual MODFLOW is a pre- and post-processor and does not affect results generated by running MT3DMS.

The same model grid dimensions, groundwater configurations, and flow parameters used in the groundwater flow model were used in the transport model.

Chemicals Selected for MT3DMS Models

Contaminant fate and transport models were constructed based on the concentrations of RDX and TNT. These chemicals were selected based on:

- Frequency of occurrence
- Detected concentrations exceeded health advisory levels established for the CHAAP site in the ROD
- Mobility in groundwater
- Nature and extent of contamination in the off-post plume

4.1.2 Modeling Assumptions

MT3DMS uses chemical characteristic input values to calculate contaminant dispersion and degradation and MODFLOW output to calculate advection (i.e., transport). MT3DMS accounts for the effects of sorption/desorption, dispersion, and natural degradation (biotic and abiotic) or other chemical reactions that can be simulated with a first-order decay rate term for the removal

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

of a chemical from the modeled system. The model cannot simulate more complicated chemical reaction systems, such as precipitation/resolution based on changing local conditions, the rate of exhaustion of bionutrients based on variable uptake by indigenous microorganisms, or the transformation of a chemical into a degradation by-product.

In addition to the general MT3DMS modeling assumptions listed in **Appendix D**, key assumptions for this modeling effort included the following:

- The steady-state MODFLOW model assumptions, setup, and results are appropriate for the contaminant transport model.
- In an effort to be conservative, off-post irrigation well pumping was not included in the groundwater contaminant fate and transport modeling simulations. Irrigation well pumping during the life of the remedial alternative would slightly shorten the expected clean-up times by removing additional contaminant mass. Historical contaminant migration data and plume geometry indicated irrigation wells have not significantly impacted contaminant migration patterns over time.
- Dissolved RDX and TNT concentrations measured from the March 1999 LTM sampling event were used to interpret isoconcentration maps. These isoconcentration maps were used as initial model input concentrations.
- Current dissolved concentrations near the source area of Load Line 1, 2, and 3 were used as the initial value for continuous source concentrations. The sources were conservatively assumed to decay to lower concentrations based on historic concentration decreases.
- RDX and TNT are subject to adsorption, dispersion, and biodegradation approximated with first-order decay rates as they are transported through the saturated zones of the aquifer.

4.2 CONTAMINANT FATE AND TRANSPORT MODEL SETUP AND INPUT PARAMETERS

The CHAAP contaminant transport model was constructed using the same overall model setup as the MODFLOW groundwater flow model. The fate and transport model setup included inputting the finite-difference grid, hydrostratigraphic layers (i.e., model layers 1 through 3), groundwater flow boundary conditions, and chemical-specific input parameters. The groundwater flow components were previously described in **Section 3**. The chemical-specific input parameters are documented in this section.

4.2.1 Initial Target Compound Concentrations

Chemical data from the March 1999 groundwater monitoring report (LTRSGWC 1999b)(**Figures 2-3 and 2-4**) were used to interpret initial individual explosive isoconcentration maps. The isoconcentration maps were used as the basis for initial concentration input to the baseline contaminant fate and transport model. Isoconcentration maps were input for the two main chemicals of concern: RDX and TNT. RDX occurs in model layers 1, 2, and 3. TNT occurs only in model layers 1 and 2.

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

Isoconcentration maps were spatially discretized into blocks of explosive concentrations matching the grid spacing used for the MODFLOW groundwater flow model. Additionally, the concentrations were assigned discrete values in a range of concentrations input to the model (e.g., 2.5, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 2500, and 2850 µg/L). A conservative approach (i.e., likely overestimating total explosive mass) was used when discretizing chemical input into the model.

Initial concentrations plots were constructed from MT3DMS results at a time period of about 1-week. These initial concentration plots are included in **Appendix E**. Considering the modeling objectives (e.g., long-term simulations), these plots were considered to be appropriate and conservative representations of the current nature and extent of contamination.

4.2.2 Continuous Source Concentrations

Groundwater monitoring results indicate there are continuing sources of dissolved explosives in groundwater at Load Lines 1, 2, and 3. The nature and extent of the current explosives plumes more closely represent plumes from continuous sources rather than slug sources. Therefore, continuous source boundary conditions were used at Load Lines 1, 2, and 3. Source concentrations were initially set equal to March 1999 results. The sources were then assigned a degradation schedule to approximate the source decay half-lives calculated from historic explosive concentration trends. That is, the modeled source area provided continuous mass input into the dissolved plume, at decreasing concentrations over time. This approach is considered conservative based on the historic concentration trends and results of natural attenuation calculations for Load Lines 1, 2, and 3 (URSGWC 1999b).

The table below summarizes continuous source data input included in **Appendix E**.

Summarized Continuous Source Input Data

Continuous Source Location		RDX		TNT	
		Initial Concentration (µg/L)	Decay Half-Life (years)	Initial Concentration (µg/L)	Decay Half-Life (years)
Load Line 1	G0023	24	5.7	130	5.7
Load Line 2	G0066	134	3.2	2850	4.0
Load Line 3	G0017	7	7.7	10	10.6

4.2.3 Contaminant Transport Model Input Parameters

MT3DMS requires the user to define each contaminant model (e.g., RDX and TNT) with a number of site-specific and chemical-specific input parameters and to make some simplifying assumptions based on existing site information. Contaminant fate and transport model input values are summarized in **Table 4-1**. The model input parameters were based on the hydrogeologic characteristics of the model layers, site chemical and geotechnical analyses, and estimates of chemical characteristics from recent literature values.

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

The input parameters for the contaminant transport models were established as follows:

- **Time (t).** MT3DMS used the steady-state, time independent, flow field generated by MODFLOW to simulate contaminant fate and transport over-time. Models were simulated until target compounds were predicted to be below the target cleanup goals.
- **Bulk Density ($\rho\beta$).** The bulk density of CHAAP soils was based on soil samples collected during installation of piezometer and monitoring wells in April and May 1998 (URSGWC 1999b). Bulk density was input the same for all three modeled layers at an average value of 118 lbS/ft³. Site-wide bulk density values ranged from 108 to 130 lbs/ ft³.
- **Dispersivity (D_L , D_T , D_V).** Chemical dispersivity input values were assumed based on varying distances chemicals have been transported from source areas. Longitudinal dispersivity (D_L) values were assumed to be ten percent of the downgradient transport distance. Longitudinal dispersivities ranged from 100 to 2500 feet. Transverse dispersivities (D_T) and vertical dispersivities (D_V) were estimated as a fraction of the longitudinal values. Longitudinal dispersivity values are typically reported to be much larger than transverse values, which are much larger than vertical values (Gelhar et al. 1992; Anderson 1979). The ratios of longitudinal to transverse to vertical dispersivity (e.g., $D_L:D_T:D_V$) were input at 10,000:1000:1. These ratios were established during model calibration based on the geometry of the existing plumes (i.e., long and narrow).
- **Biodegradation Half-life ($t_{1/2}$).** Historical concentration data were used to establish contaminant reduction trends and estimate biodegradation half-lives (URSGWC 1999b). The methodologies of Graves (1995) and Buscheck and Alcantar (1995) were used to establish a range of estimated half-lives for RDX and TNT. These methods were used for three distinct plume areas. These areas included: on-post source areas, feedlot area, and the distal plume. Biodegradation half-life analysis is included in **Appendix E**. RDX and TNT half-life values input to the model in each area are shown in the table below.

Biodegradation Half-life Input

Plume Location	RDX Half-life (years)	TNT Half-life (years)
On-Post	5.7	5.7
Feed Lot	4.3	2.5
Distal Plume	8.9	5.7

Half-life values were input to the model as first-order decay constants (k) using $k = \ln(2)/t_{1/2}$. These values were selected from the upper range of estimated values to conservatively estimate biodegradation rates for the natural attenuation evaluation. These values were considered to be representative of natural decay processes occurring at the site based on the current distribution of explosives and the results of the long-term monitoring of natural attenuation field parameters (URSGWC 1999b).

- **Organic Carbon/Water Partition Coefficient (K_{oc}).** Organic carbon/water partition coefficient (K_{oc}) values selected for each chemical were based on mean values estimated from a range of reported literature values (Townsend 1996). RDX and TNT values input to the model were 1.17 ft³/lb (73 mL/g) and 8.41 ft³/lb (525 mL/g), respectively.

APPENDIXC Numerical Groundwater Contaminant Fate and Transport Backup

- **Total Organic Carbon (TOC).** The TOC content of CHAAP soils was based on soil samples collected during the June 1998 LTM sampling event (URSGWC 1999b). TOC was input the same for all three modeled layers at a value of 0.089 percent. Site wide TOC values range from about 0.2 percent to 0.04 percent.
- **Sorption Distribution Coefficient (K_d).** Soil/water partition coefficients (K_d) were estimated for each chemical from the product of the K_{oc} and TOC values listed above. RDX and TNT values input to the model were 6.5×10^{-11} ft³/lb and 4.7×10^{-10} ft³/lb, respectively.
- **Retardation Factor (R).** The model uses the bulk density, the sorption coefficient, and effective aquifer porosity to calculate a retardation factor using the following equation:

$$R = 1 + \frac{K_d \cdot \rho \beta}{\eta}$$

Using the above values, retardation factors of 1.5 and 4.5 were calculated by the model for RDX and TNT, respectively.

4.3 BASELINE CONTAMINANT FATE AND TRANSPORT MODEL CALIBRATION, SENSITIVITY, AND LIMITATIONS

The contaminant fate and transport model setup and input parameters were calibrated to accurately simulate the extent of the current explosives plume and predict future behavior of the plume. This effort included qualitative model calibration, sensitivity analysis, and understanding the limitations of the model predictions.

4.3.1 Contaminant Fate and Transport Model Calibration

Contaminant fate and transport model setup and calibration were completed to reproduce the current chemical concentrations at the site as closely as possible. An iterative calibration process was used to refine MT3DMS input based on model-predicted results. Historical source release information (e.g., mass release and dates of multiple releases) cannot be accurately estimated because of the multiple nature of the source releases over time. Therefore, calibration of the contaminant fate and transport model relied on 1996 to 1999 groundwater monitoring data, and the more conventional method of inputting sources at the original time of release was not implemented. The calibration procedures completed included:

- Discretizing current RDX and TNT concentrations into the various layers to closely simulate current conditions.
- Using historical data to calculate degradation rates for various source and plume areas. For example Load Line 1, Load Line 2, Load Line 3, feed lot area, and distal plume.
- Using historical and current data to develop continuous source input.
 - Initial values based on March 1999 sample results
 - Degradation rates based on historic concentration trends
 - Lateral and vertical spatial distribution based on current and historic plume geometry and concentration distribution

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

- Discretizing dispersivity based on distance contaminant traveled from the source area.
 - Longitudinal Dispersivity (D_l) = 1/10 transport distance
 - Ratio of longitudinal to transverse to vertical dispersivity (e.g., $D_l:D_t:D_v$) determined from historic and current plume geometry

These parameters were systematically varied until the model-predicted plume behavior most accurately simulated the existing plume and historical trends.

4.3.2 Contaminant Fate and Transport Model Sensitivity

Sensitivity of the contaminant fate and transport model was evaluated qualitatively to describe possible variability in the subsequent model-predicted remedial alternative results. Contaminant fate and transport modeling was sensitive to both the contaminant and groundwater flow input parameters. **Section 3.3.2** summarized the groundwater flow model sensitivity to groundwater flow input parameters. Contaminant fate and transport sensitivity to groundwater flow input was not specifically evaluated. Generally contaminant fate and transport sensitivity was analogous to the groundwater flow model sensitivity to groundwater flow input parameters.

The contaminant fate and transport results were sensitive to most contaminant fate and transport input parameters. These parameters included: continuous source concentrations, initial concentrations, biodegradation half-life, retardation factor, and dispersivity. Fluctuating these parameters within reasonable estimated ranges created noticeable differences in model-predicted results.

The degree of contaminant fate and transport model sensitivity to contaminant specific input parameters was variable. Qualitative sensitivity analysis results are summarized in the table below.

Summary of Contaminant Fate and Transport Model Sensitivity

Input Parameter	Sensitivity	Summary
Continuous Source	High	↓ Mass - ↓ Clean-up time ↑ Decay rate - ↓ Clean-up time
Initial Concentration	High	↓ Mass - ↓ Clean-up time
Biodegradation Half-life	Moderate	↑ Decay rate - ↓ Clean-up time
Retardation Factor	Moderate	↑ Retardation factor - ↓ Transport distance
Dispersivity	Low	↓ Dispersivity - ↓ Transport distance

4.3.2 Contaminant Fate and Transport Model Limitations

Limitations of the contaminant fate and transport model are directly related to the model assumptions listed in **Section 4.1.2** and **Appendix D**. These limitations included a single

APPENDIXC Numerical Groundwater Contaminant Fate and Transport Backup

concentration value within each cell, equilibrium-controlled sorption/desorption, and irreversible linear decay rates. The largest limitations for the CHAAP site include:

- Continuous source and dissolved explosive decay rates were estimated model input and not model-calculated over time as the natural attenuation capacity of the aquifer (e.g., assimilative capacity) changed. These estimated sources had little to no effect on explosives modeling results off-post because of low off-post explosive concentrations and very high assimilative capacity of the aquifer.
- Target explosives calibration was limited to the current interpreted plumes and historic trends.

These limitations were compensated for by:

- Conservative mass input at the continuous groundwater source areas (i.e., likely overestimating mass)
- Conservative initial concentration input (i.e., likely overestimating mass)
- Chemical and location specific degradation rates

4.4 CONTAMINANT FATE AND TRANSPORT MODEL-PREDICTED RESULTS

After model calibration and sensitivity analysis indicated the model reasonably predicted contaminant fate and transport, the model was used to predict baseline contaminant fate and transport conditions. Then the model was used to predict the effectiveness of the groundwater remediation alternatives previously analyzed using the groundwater flow model. This evaluation was completed using the MT3DMS contaminant fate and transport model. Four different groundwater remediation alternatives were evaluated with MT3DMS. The four alternatives included:

- Baseline Contaminant Fate and Transport Conditions (e.g., Natural Attenuation with no remedial groundwater pumping)
- Optimized On-Post Extraction with Off-Post Natural Attenuation
- Optimized On-Post Extraction with EW-7 and Off-Post Natural Attenuation
- Optimized On-Post Extraction with EW-7 and Distal Extraction

The baseline contaminant fate and transport conditions used the steady-state, non-pumping groundwater flow pattern to predict contaminant transport under natural groundwater flow conditions. This alternative was modeled to compare pumping alternatives to a baseline alternative. Excluded from contaminant fate and transport remedial alternative modeling are the design extraction rate and original operating extraction rate alternatives. These alternatives were shown to be ineffective during groundwater flow modeling.

Remedial alternative evaluation was based on contaminant fate and transport model-predicted clean-up times. Model-predicted clean-up times represent the time predicted for explosive concentrations to decrease below the target cleanup goals. Clean-up times were evaluated for three plume areas: 1) on-post, 2) feed lot area, and 3) distal plume. The results of this evaluation

APPENDIX C Numerical Groundwater Contaminant Fate and Transport Backup

are shown on **Table 4-2**. For comparative purposes, model predicted results for RDX and TNT are shown on **Figures 4-1** and **4-2**, respectively. These figures show results of the alternatives described below.

4.4.1 Baseline Contaminant Fate and Transport

A baseline MT3DMS contaminant fate and transport model was constructed using the current explosive concentrations and extents interpreted from the March 1999 LTM results (URSGWC 1999b). Contaminant transport under this hypothetical alternative assumes no groundwater removal from the affected area. For example, no remedial extraction well, irrigation well, or domestic well pumping. Model-predicted clean-up times for the baseline contaminant fate and transport conditions were:

- Distal Plume – 13 years
- Feedlot Area – 33 years
- On-post – 50 years

4.4.2 Optimized On-Post Extraction with Off-Post Natural Attenuation

The optimized on-post extraction with off-post natural attenuation alternative described in **Section 3.4.3** was evaluated using MT3DMS. Contaminant transport under this alternative simulated the performance of the current remedial system into the future. Model-predicted cleanup times for the optimized extraction rate alternative were:

- Distal Plume – 13 years
- Feedlot Area – 19 years
- On-post – 45 years

Model-predicted results indicated on-post pumping did not significantly impact contaminant fate and transport of the existing off-post plume. However, model-predicted results indicated the off-post plume will naturally attenuate to below target clean-up goals in about 20 years.

4.4.3 Optimized On-Post Extraction with EW-7 and Off-Post Natural Attenuation

The optimized on-post extraction with EW-7 and off-post natural attenuation alternative described in **Section 3.4.4** was evaluated using MT3DMS. Contaminant transport modeled with this alternative simulated the performance of the proposed, currently under construction, system into the future. Model-predicted clean-up times for the optimized extraction rate with additional well alternative were:

- Distal Plume – 11 years
- Feedlot Area – 19 years
- On-post – 45 years

APPENDIXC Numerical Groundwater Contaminant Fate and Transport Backup

Model-predicted results indicated on-post pumping did not significantly impact contaminant fate and transport of the existing off-post plume. However, model-predicted results indicated the off-post plume will naturally attenuate to below target clean-up goals in about 20 years.

4.4.4 Optimized On-Post Extraction with EW-7 and Distal Extraction

The original remedial alternative design (Rust 1996) included three distal extraction wells. During construction of the on-post portion of the remedial design, real estate agreements could not be reached that would facilitate the off-post piping network associated with distal extraction wells. This prohibited the distal wells from being constructed. Subsequent to this delay, the distal plume appeared to be declining in size and concentration (URSGWC 1999b).

The distal extraction alternative was evaluated to determine if distal extraction would decrease the optimized extraction alternative clean-up time.

The optimized on-post extraction with EW-7 and distal extraction alternative described in **Section 3.4.5** was evaluated using MT3DMS. Contaminant transport modeled with this alternative simulated the performance of the proposed, currently under construction, system with the addition of three distal wells. Model-predicted clean-up times for this alternative were:

- Distal Plume – 11 years
- Feedlot Area – 19 years
- On-post – 45 years

4.5 CONTAMINANT FATE AND TRANSPORT MODELING CONCLUSIONS

Contaminant fate and transport modeling of extraction alternatives indicated the optimized on-post extraction with EW-7 and off-post natural attenuation alternative would remove contamination emanating from Load Lines 1, 2, and 3, and contain the on-post contamination. Model-predicted results indicated distal extraction would not decrease the overall clean-up times significantly.

SECTION FIVE

Conclusions and Recommendations

Groundwater flow modeling of extraction alternatives indicated the current system could be enhanced and optimized to capture contamination emanating from Load Lines 1, 2, and 3. The optimized on-post extraction with an additional well (i.e., EW-7) alternative was recommended (URSGWC 1999a) to provide effective containment of the on-post explosives plume. The recommended alternative included:

- Eliminating pumping from EW-1, EW-2, and EW-3 because contaminants were below the health advisory level
- Increasing extraction rates at EW-4, EW-5, and EW-6
- Installation of an additional well at the post boundary

Contaminant fate and transport modeling results confirmed the recommendation made during the groundwater flow modeling (URSGWC 1999a). The recommended alternative remains optimized on-post extraction with an additional well (i.e., EW-7) and natural attenuation of the off-post plume. This recommendation is supported by declining explosives concentrations off-post and the model-predicted response of the explosives plume to on-post extraction. Key model-predicted results in support of this recommendation include:

- Model-predicted on-post clean-up time decreased by 5 years due to on-post extraction
- Model-predicted feedlot clean-up time decreased by 14 years due to on-post extraction
- Model results indicated distal well pumping would not decrease off-post cleanup times

EW-7 has been constructed and operated since the spring of 2000. Water level data indicate EW-7 provides containment of the on-post explosive plume. Continued operation of EW-7 at a minimum of 250 gallons per minute is recommended.

TABLE 4-1
CONTAMINANT FATE AND TRANSPORT MODEL INPUT PARAMETERS

Modeled Chemical and Location	Constant Source (initial concentration - degradation half-life) ¹	Biodegradation Half-Life (t _{1/2} - years) ²	First Order Rate Constant (k - 1/day) ³	Sorption Coefficient (k _d - ft ³ /lb) ⁴	Retardation Factor (R) ⁵	Dispersivity (D _i - feet) ⁶	Dispersivity Ratio (D _i :D _i :D _i :D _v) ⁷
RDX							
- Distal Plume	--	8.9	2.1E-04	6.5E-11	1.5	800 to 2500	1,000:1; 10,000:1
- Feed Lot Area	--	4.3	4.4E-04	6.5E-11	1.5	400 to 800	1,000:1; 10,000:1
- On-Post	--	5.7	3.3E-04	6.5E-11	1.5	100 to 400	1,000:1; 10,000:1
Load Line 1	24 µg/L at 5.7 years	--	--	--	--	--	--
Load Line 2	134 µg/L at 3.2 years	--	--	--	--	--	--
Load Line 3	7 µg/L at 3.2 years	--	--	--	--	--	--
TNT							
- Distal Plume	--	5.7	7.6E-04	4.7E-10	4.5	800 to 2500	1,000:1; 10,000:1
- Feed Lot Area	--	2.5	7.6E-04	4.7E-10	4.5	400 to 800	1,000:1; 10,000:1
- On-Post	--	5.7	3.3E-04	4.7E-10	4.5	100 to 400	1,000:1; 10,000:1
Load Line 1	130 µg/L at 3.2 years	--	--	--	--	--	--
Load Line 2	2850 µg/L at 3.2 years	--	--	--	--	--	--
Load Line 3	10 µg/L at 3.2 years	--	--	--	--	--	--

Notes: ¹ Estimated from March 1999 sample results, historic explosives trends (URSGWC 1999), and calibrated model-predicted results.

² Estimated from historic explosive concentration trends (URSGWC 1999) and calibrated model-predicted results.

³ $k = \ln(2)/t_{1/2}$

⁴ $K_d = K_{oc} * TOC$; RDX $K_{oc} = 1.17 \text{ ft}^3/\text{lb}$ and TNT $K_{oc} = 8.41 \text{ ft}^3/\text{lb}$ (Townsend 1996); TOC=0.089% (URSGWC 1999).

⁵ $R = 1 + (\rho\beta * K_d)/\eta$; $\rho\beta = 118 \text{ lb}/\text{ft}^3$ and $\eta = 0.25$ (URSGWC 1999)

⁶ Assumed D_i valued based on 1/10 transport distance (Gelhar et al. 1992, Anderson 1979)

⁷ D_i and D_v based on existing and calibrated model-predicted plume geometries.

TABLE 4-2
MODEL-PREDICTED CLEAN-UP TIMES ¹ (years)

Alternative ²	On-Post		Feedlot Area		Distal Plume	
	RDX	TNT	RDX	TNT	RDX	TNT
³ Baseline Fate and Transport Conditions	24	50	15	33	13	12
⁴ Optimized On-post Extraction with Off-Post Natural Attenuation	24	45	15	19	13	6
⁵ Optimized On-post Extraction with EW-7 and Off-post with Natural Attenuation	24	45	13	19	11	6
⁶ Optimized On-post Extraction with EW-7 and Distal Extraction	24	45	13	19	11	6

Notes:

¹ Clean-up time represents model-predicted year when all results are below 2 µg/L.

² See Figures 3-10, 3-11, and 3-12 for remedial pumping alternative details.

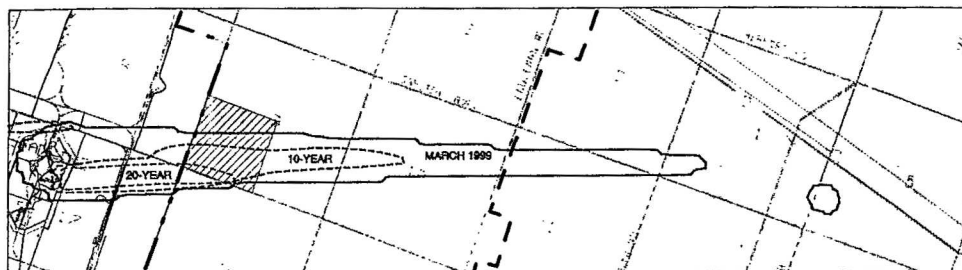
³ No remedial groundwater pumping.

⁴ Remedial groundwater pumping; EW-4 at 75 gpm, EW-5 at 225 gpm, and EW-6 at 450 gpm.

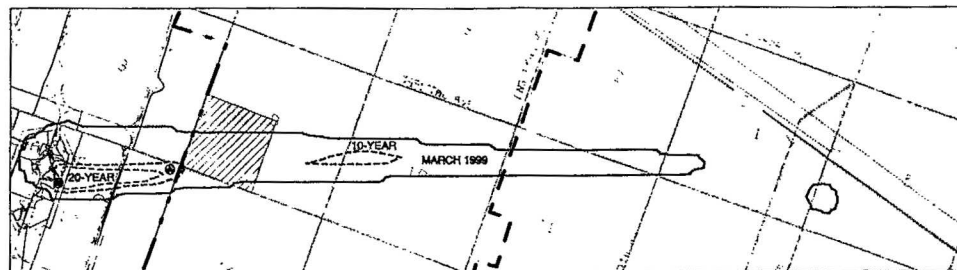
⁵ Remedial groundwater pumping; EW-4 at 75 gpm, EW-5 at 225 gpm, EW-6 at 200 gpm, and EW-7 at 250 gpm.

⁶ Remedial groundwater pumping using optimized pumping with EW-7 plus; Distal-1 at 150 gpm, Distal-2 at 700 gpm, and Distal-3 at 300 gpm.

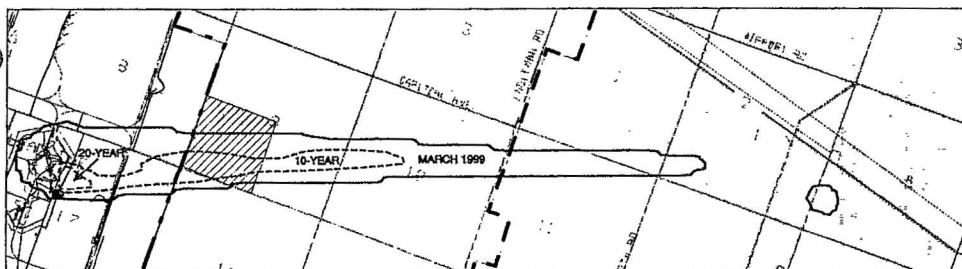
BASELINE FATE AND TRANSPORT CONDITIONS



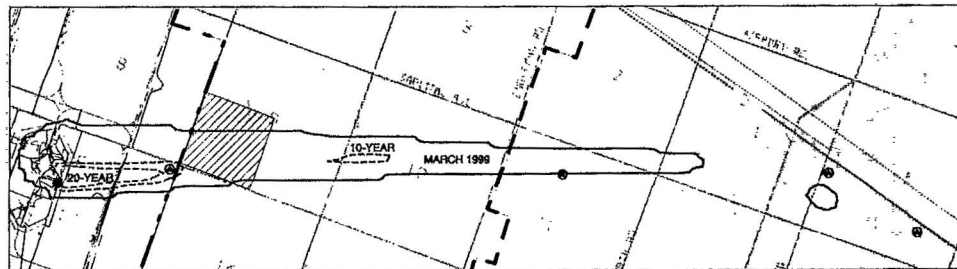
OPTIMIZED ON-POST EXTRACTION WITH EW-7 AND OFF-POST NATURAL ATTENUATION



OPTIMIZED ON-POST EXTRACTION WITH OFF-POST NATURAL ATTENUATION



OPTIMIZED ON-POST EXTRACTION WITH EW-7 AND DISTAL EXTRACTION



LEGEND

- FACILITY BOUNDARY
- - - GRAND ISLAND CITY LIMITS
- ▨ FEEDLOT AREA
- GROUNDWATER EXTRACTION WELL

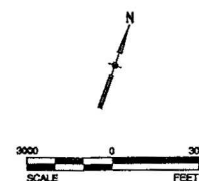
- HORIZONTAL EXTENT OF ROX MARCH 1999
- MODEL-PREDICTED HORIZONTAL EXTENT OF ROX (CONCENTRATIONS >3μg/L) AT 10 YEARS (2010)
- MODEL-PREDICTED HORIZONTAL EXTENT OF ROX (CONCENTRATIONS >3μg/L) AT 20 YEARS (2020)

NOTES:

DATA SHOWN ARE FROM MODEL LAYER 2. MTSDMS PREDICTED THE LONGEST CLEAN-UP TIMES IN LAYER 2. TABLE 4-2 LISTS SPECIFIC MODEL-PREDICTED CLEAN-UP TIMES.

MARCH 1999 RESULTS ARE MODEL-PREDICTED RESULTS AT 7 DAYS.

SEE FIGURES 3-10, 3-11, AND 3-12 FOR DESCRIPTIONS OF MODELED ALTERNATIVES.

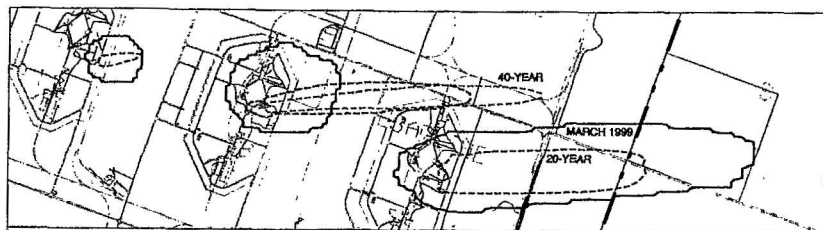


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COMPARISON OF REMEDIAL ALTERNATIVES -
MODEL-PREDICTED ROX TRANSPORT OVER TIME

DRN BY: JSH	DATE: 8/12/00	PROJECT NO: 48-F000942.00	FIG. NO: 4-1
CHKD BY:	REVISIONS: 0		

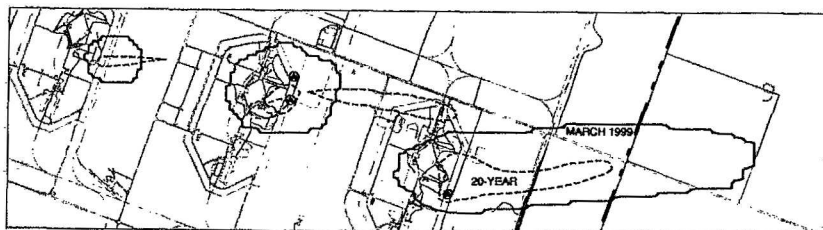
BASELINE FATE AND TRANSPORT CONDITIONS



OPTIMIZED ON-POST EXTRACTION WITH EW-7 AND OFF-POST NATURAL ATTENUATION



OPTIMIZED ON-POST EXTRACTION WITH OFF-POST NATURAL ATTENUATION



OPTIMIZED ON-POST EXTRACTION WITH EW-7 AND DISTAL EXTRACTION



LEGEND

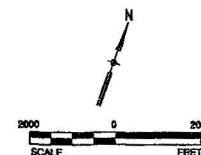
- | | | | |
|--|-----------------------------|--|---|
| | FACILITY BOUNDARY | | HORIZONTAL EXTENT OF TNT MARCH 1999 |
| | FREE LOT AREA | | MODEL-PREDICTED HORIZONTAL EXTENT OF TNT (CONCENTRATIONS >2ug/L) AT 20 YEARS (2020) |
| | GROUNDWATER EXTRACTION WELL | | MODEL-PREDICTED HORIZONTAL EXTENT OF TNT (CONCENTRATIONS >2ug/L) AT 40 YEARS (2040) |

NOTES:

DATA SHOWN ARE FROM MODEL LAYER 1. MT30MS
PREDICTED THE LONGEST CLEAN-UP TIMES IN LAYER 1.
TABLE 4-2 LISTS SPECIFIC MODEL-PREDICTED CLEAN-UP
TIMES.

MARCH 1999 RESULTS ARE MODEL-PREDICTED RESULTS
AT 7 DAYS.

SEE FIGURES 3-10, 3-11, AND 3-12 FOR DESCRIPTIONS OF
MODELED ALTERNATIVES.



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COMPARISON OF REMEDIAL ALTERNATIVES -
MODEL-PREDICTED TNT TRANSPORT OVER TIME

DRN. BY: JSH	DATE: 9/26/99	PROJECT NO: 46-F0000642.00	FIG. NO: 4-2
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